INSECTS

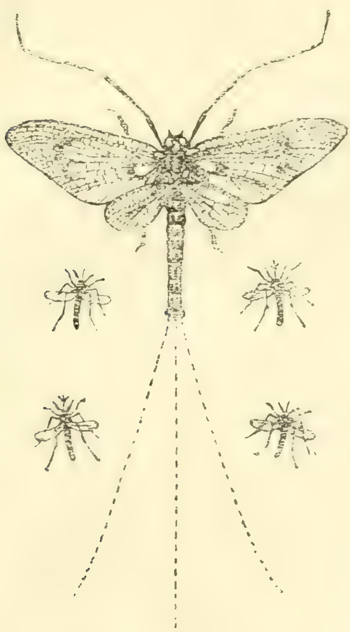
THEIR LIFE-HISTORIES AND HABITS

PLATE I

Protective Resemblance: *Kallima inachis* with wings expanded, and two specimens with closed wings. India

INSECTS
THEIR LIFE-HISTORIES AND HABITS

BY HAROLD BASTIN



LONDON: *Published by* T. C. & E. C. JACK
67 LONG ACRE, W.C. : AND EDINBURGH
1913

PREFACE

In the following pages an attempt is made to set forth, in simple terms, the salient facts of entomology—that branch of science which treats of insects. It has been said truly that a man might devote his whole life to the study of only one insect without exhausting the possibilities of his subject. Consequently, a work such as the present must be in great measure a compilation, and I freely acknowledge my indebtedness to a large body of workers who have placed on record their observations concerning the structure and habits of insects. I believe that I am especially beholden to the writings of Lord Avebury, Professor G. H. Carpenter, Sir E. Ray Lankester, Professor E. B. Poulton, and Dr. David Sharp, but in almost every instance where an important fact or conclusion is re-stated, the name of the authority is given in the context.

I desire to offer my thanks to Mr. Oswald H. Latter, of Charterhouse, for his kindness in reading and criticising the proofs of this book. My thanks are also due to my friend, Mr. Sidney J. Miller, who prepared for me the drawings and diagrams which are reproduced on Plates VII, VIII, IX, XI, and XII.

H. B.

Reading, 1913.

CONTENTS

LIST OF ILLUSTRATIONS

INSECTS: THEIR LIFE-HISTORIES AND HABITS

CHAPTER I

THE DOMINANT INSECT

Many people call every small creeping thing an insect, but this is incorrect. A bat, though it flies in the air, is not a bird; a whale, though it swims in the sea, is not a fish; nor is an animal necessarily an insect because it creeps and is small. In other words, insects display certain peculiarities which mark them off from all other animals; and with these we must first deal by way of introduction. Perhaps the easiest way to recognise an insect at sight is to count its legs. All insects have six legs, neither more nor less, although some young insects, called caterpillars, which pass their days clinging to wind-rocked leaves and twigs, possess in addition certain fleshy appendages termed claspers or prolegs. But these are mere temporary supports, provided to meet a special contingency. They disappear ere their owners become adult, and in no way alter the fact that insects are a six-legged race. Another peculiarity of the typical insect is its possession of wings—sometimes two, more often four. In its capacity for flight the insect is alone among invertebrate animals. Thus, by applying the wing and leg test, it becomes a simple matter to pick out an insect from such questionable creatures as spiders, crabs, and centipedes. As a spider has eight legs, a crab ten, and a centipede a

still larger number, and as none of these creatures has any sign of wings, we are able at once to deny them the proud name of insect.

Insects are a dominant race, and the secret of their success rests with their peculiar fitness for the life which they lead. Regarded as a machine, an insect is more cunningly designed, more perfectly equipped, than any other invertebrate type. Just as man is chief of the animals with backbones, the most successful example that the world has yet seen, so insects are the leading race of the invertebrate class. We shall do well to fix firmly in our minds that an insect is planned quite differently from such animals as rabbits, birds, and fishes. It possesses no internal skeleton, but its skin is permeated with a peculiar substance called chitin (the "ch" is pronounced like "k"), which is remarkably hard and durable, and is unaffected by almost all ordinary acids and alkalies. It is, in fact, well calculated to resist the weather, and to sustain the wear and tear of an active life. Thus, for practical purposes, we may regard an adult insect as living within a suit of strong, light armour, to the inner walls of which its muscles are attached to give them the leverage necessary for their play. This suit of armour is divided into three compartments. The first encases the head; the second, from which spring the six legs and the wings, protects the chest or thorax; while the third envelops the hind-body or abdomen.

Like the children of Esau, insects are essentially a hairy race. Hairs long and short, differing widely in form, are found on all parts of their bodies. These frequently determine the colour of an insect, and constitute its chief ornament. The humble-bee, for example, has its body banded alternately with orange and black hairs, while the so-called scales of a butterfly's wings are really

hairs, flattened and otherwise modified. The hairs of many bees have been planned with a view to pollen-gathering, and are curiously branched or twisted. Still other hairs are stiff and sharply pointed, or hollow, brittle, and filled with poison, like the stinging hairs of a nettle. They constitute an effective *chevaux de frise* which serves to keep enemies at bay. Again, many insects' hairs are end-organs of sense. They pass right through minute pores in the chitinous armour, and their roots are in direct communication with nerves. By means of these hairs insects receive impressions from the world around them. They have hairs of touch, hairs of taste, hairs for smelling, and hairs which are thought to serve the sense of hearing.

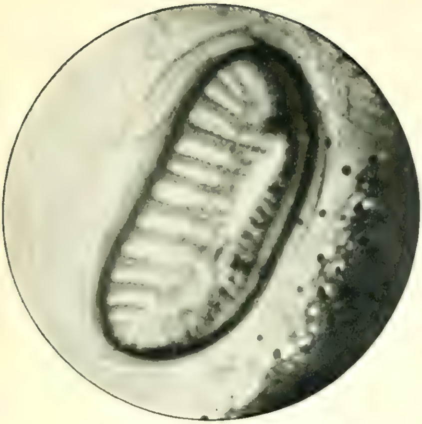
The great compound eyes invest the insect's head with a quaint resemblance to a diver's helmet; but, in addition to these huge orbs, there are often three smaller eyes, far less complex in their structure, arranged in a triangle upon the brow. The head, too, carries a single pair of feelers, or antennæ—important sense-organs which vary widely both in form and function.

The mouth of an insect is equipped with a set of parts which are wonderfully fashioned, in the case of each species, to accord with the method of feeding and the kind of food which is eaten. Moreover, the mouth-parts are often modified in such a way that they become, in effect, highly specialised tools. I shall recur to this matter in a subsequent chapter. For the moment I need only point out that there is one office which the mouth of the insect does not serve—viz. that of respiration. An insect breathes through a number of small holes in its side, called spiracles. The orifice of each spiracle is beset with hairs, which serve to keep out dust; while just within there is an ingenious little valve which is opened and

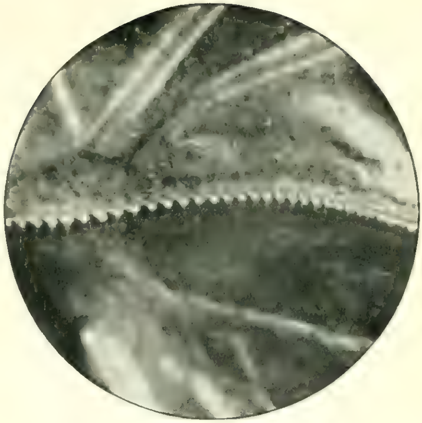
closed by muscular contraction. The air which enters the spiracles is conveyed direct to every part of the body through a system of minute pipes, known as tracheæ, the final ramifications of which are so delicate that they penetrate the most distant extremities, such as the eyes and the tips of the antennæ. The tracheæ are soft tubes within which run spirally coiled threads of chitin. They are, in fact, exact counterparts in miniature of our wire-lined rubber gas-tubing. Their structure is a safeguard against short circuit. The elastic chitinous coil keeps the trachea open even when it is subjected to pressure, as by the bending of a joint through which it passes, while the flexibility of the tube is not impaired. Owing to this singular method of breathing, the blood of the typical insect has little or nothing to do with the aeration of its tissues. Its function is almost wholly nutritive. Moreover, the blood (which is usually colourless, though sometimes green or yellow) does not flow through a system of arteries and veins. True, the insect has a chambered heart from which the blood passes into a pulsating tube or aorta; but from this it is pumped direct into the body cavity, where it circulates freely, bathing all the organs, receiving nutriment from the food canal, giving up its waste matter to the kidneys and tracheæ, and visiting the limbs. Finally, it re-enters the heart through valvular slits in the walls of its chambers. The insect's heart is a comparatively large, long organ, situated above the digestive canal, and immediately beneath the chitinous armour of the back. Its aorta, or pumping tube, passes into the head and discharges its stream of blood above the brain.

Of the insect's digestive system little need be said. It comprises, among other parts and appendages, a crop, a gizzard, a stomach, and an intestine. Moreover (and

Plate II

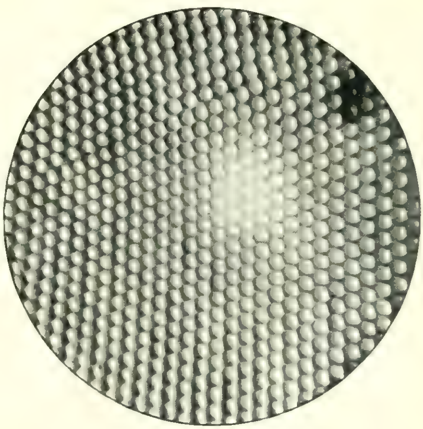


Spiracle of a Beetle



File-like stridulating ridge on the wing of a Cricket

Tracheæ of the Silkworm



Part of the eye-surface of a Beetle

(All photo-micrographs)

this is an important point) it has proved capable of limitless adjustment and alteration: so that at the present day we find insects feeding upon and digesting almost every substance from which nutriment can be extracted. Beneath the digestive canal (not above it as in the case of vertebrate animals) passes the central nervous chain of the insect. This is composed of twin cords which connect a series of paired knobs, called ganglia. Roughly speaking, each pair of ganglia may be likened to a minor brain which governs the activities of the parts that immediately surround it. This arrangement accounts for the curious disconnectedness of action which is observable in a maimed insect. The brain within the head innervates the eyes and antennæ, and is, as it were, the centre of will-power in regard to the movements of the wings and legs. Thus, an insect deprived of its brain cannot go to its food, though it is able to eat if food be placed in contact with its mouth—the explanation being that the actions of the mouth are regulated by one of the minor brains. Again, although the brainless insect cannot move intelligently in a given direction, it remains capable of aimless locomotion. Deprived of its head, it can walk or fly for hours, possibly until starvation supervenes. Similarly, the detached abdomen will long continue the muscular movements incident to respiration, just as though it were still part of a complete organism.

A recapitulation of the foregoing points will serve to emphasize the fact that the typical insect possesses a combination of qualities eminently calculated to command success. Firstly, insects stand firmly. Their six legs, a double tripod, afford the best mechanical base of support. In walking or running the legs are moved forward in sets of three—the first and third legs on the one side, the second on the other; so that a tripod always

remains to ensure a firm foothold. Still more valuable is the insect's power of flight. Its wings enable it to voyage far and wide over land and sea in search of food. It has the power to colonise, to found families in promising localities, to migrate, like a bird, before severities of climate. Thirdly, the insect has a noble head, equipped with marvellous sense-organs and a tool-box mouth. The wherewithal of a sound digestion constitutes a fourth qualification for success. It enabled insects to diversify their ways of feeding as they began to increase and multiply upon the face of the earth. They were able to put up with what they could get—to "rough it." No spot was too barren, no food too meagre, for their support. Fifthly, the systems of circulation and respiration which obtain among insects are highly favourable to a vigorous, pushful life. The tissues are constantly bathed in nutritive fluid, and permeated with oxygen, the inevitable result being abundant energy. Ceaseless activity is a fundamental law of insect existence, as one may realise by watching a bee or an ant during the hours of a summer day. Ants are known to toil also by moonlight in warm weather. A tired insect exists only in the fancy of the poet.

Insects undoubtedly possess great muscular force, but their feats of strength have often formed the subject for unwarrantable exaggeration. "By general reasoning of a quite simple kind" (I quote from "The Cockroach" by Miall and Denny) "it can be shown that, for muscles possessing the same physical properties, the *relative* muscular force necessarily increases very rapidly as the size of the animal decreases. For the contractile force of muscles of the same kind depends simply upon the number and thickness of the fibres: *i.e.* upon the sectional area of the muscles. If the size of the animal and of

its muscles be increased according to any uniform scale, the sectional area of a given muscle will increase as the square of any lineal dimension. But the weight increases in a higher proportion, according to the increase in length, breadth and depth jointly, or as the cube of any linear dimension." This principle may be readily demonstrated by a simple experiment in mechanics. We may first take a cubical block of wood, and place it upon a square column of the same material. If we now double all the dimensions, which may be done by fitting together eight cubes like the first, and four columns also the same as before, but twice as long, we shall find that each column has to bear double the original weight, albeit the base of each, and consequently its strength, remains unaltered. It is clear, therefore, that the *apparent* strength of an insect is liable to misconception, for the reason that its muscles have proportionately far less work to do than those of larger animals, the contractile, or pulling, force of each muscle increasing rapidly as the size of the animal decreases. According to Straus-Dürckheim, a flea can leap a foot high—a feat equal to raising 200 times its own weight; yet this is really less remarkable than a schoolboy's leap of two feet, for it indicates exactly the same efficiency of muscles and other leaping apparatus as would be implied in a full-grown man's leap of the same height, viz. one foot.

When summing up the success-compelling attributes of the insect, we must not ignore the changes of habit which are accomplished during the progress of its life-history. I shall deal more fully with this matter in the next chapter. But I should like at once to remind the reader that whereas a caterpillar eats leaves, a butterfly sucks nectar from the flowers. This ability to feed in

different ways, and upon different substances, in successive periods of their development is very general among insects, and it has doubtless contributed largely to the success of the race. The drain upon a particular food-stuff is lessened, while the risk of lean years consequent upon a period of wantonness is avoided.

These, then, are the chief qualities that have made insects successful. Does the reader ask for evidence that they have truly succeeded? Let him take his stand in a field or a coppice on any spring or summer day. He will see, perhaps, a bird or two, a rabbit, a mouse, and a lizard. But for every animal of another class, scores of insects will meet the eye. Flies hover in the air, bees and butterflies pass from flower to flower, beetles climb the grass stems or scuttle across the sun-dried patches of earth. A similar comparison may be made within the walls of one's own home. A few mice, some spiders, possibly a rat—these are perforce our lodgers; but in addition we are liable to support at least a score of different insects. There is the familiar cockroach—the "black beetle" of our kitchen, the cheerful cricket on the hearth, clothes moths in the wardrobe, beetles burrowing in the woodwork, book-lice among old papers, and flies upon the window-pane—to enumerate only a few of these unbidden guests. Moreover, what is true of the house, and of the English country-side, holds good the world over. Insects predominate from the tropics to the poles, wherever animal life can exist. It is computed that 500,000 different kinds of insects are actually known and named; hundreds more are being classified each year; while it is safe to estimate the total number of existing species as at least a million.

The geographical range of insects is truly astonishing. Butterflies are found beyond the polar circle, and

mosquitoes, the intrepid arctic explorers of the insect world, have passed the seventy-second line of north latitude. A small species of butterfly was captured on a mountain in Ecuador 16,500 feet above sea-level. There are desert insects dwelling where no water is, while others have penetrated the very bowels of the earth, for the subterranean galleries and chambers of limestone districts have an insect population all their own. Several kinds are known to inhabit the cavern of Mitchelstown in the south of Ireland, while dozens of species, including crickets and beetles, have been found within the vast caves of Carniola in Austria and of Kentucky in North America. Certain of these insects seem to have strayed underground quite recently, for they differ little in appearance from their relatives which enjoy the sunlight and free air. But others are the lineal descendants of ancestors which espoused a subterranean life countless centuries ago. These hereditary cave-dwellers are pale and wan, like captive exiles of a Siberian mine. All of them are blind. Indeed, diligent dissection beneath the microscope often fails to reveal any trace of the eye or of the optic tracts of the brain. Possibly the sense of touch alone remains with these strange insects. Yet they pass their lives in well-ordered activity. The lesser eat the red earth which covers the floors of their galleries, subsisting upon the minute particles of vegetable matter which it contains—the fragmental decay of fungi which grow within the caves, or of other plants carried there by subterranean streams. Upon the lesser the larger species prey. Thus the old drama of life is enacted in these silent caverns, far from the light of day.

Many insects have likewise invaded the fresh waters of the globe, and these exhibit remarkable modifications which fit them for an aquatic life. In a subsequent

chapter I shall have more to say about water insects and their ways. They form a very numerous group; but while some of them are entirely aquatic, the majority spend only their youth in stream or pond, and join the ranks of flying insects when they become adult. A very few insects actually dwell in hot springs, disporting themselves, so to speak, in a life-long Turkish bath. Many species, especially beetles, inhabit the sea-shore, and are submerged twice daily by the tides. They lurk under stones or among weeds, and the close-set hairs of their bodies entangle sufficient air for their needs until the waters abate. For the time being they dwell in a kind of air jacket, after the manner of the well-known water-spider. Water-skating bugs, near relatives of those which skim the surface of the village pond, glide over the calm seas of the tropics, often hundreds of miles from land. They make their home upon the waste of waters, and rest upon weeds or wreckage. Their eggs have been picked up attached to the floating feather of a sea-bird. Yet insects as a whole have not taken kindly to a seafaring life. Not one species is known to dwell continually in salt water; while those which frequent the shore, or are otherwise associated with the sea in the course of their lives, constitute a very small part of the world's total insect population.

We have seen that the wonderful geographical range of the insect is due to its exceptional natural endowments, especially to its power of flight. Aided by the wind, insects are known to accomplish astonishing journeys. Swarms of migratory locusts have been met with at sea a thousand miles from land, while there is reason for thinking that the Biblical locust actually crossed over in prehistoric times to the Old World from South America, in which continent it still persists. Certain supremely

vigorous and assertive insects have become almost cosmopolitan in their range. Among these is the familiar painted lady butterfly which is found in all quarters of the globe, with the exception of South America, where its place is taken by a closely allied species. The tiny codlin moth—a well-known "pest"—occurs wherever the apple is cultivated; while certain beetles, such as the grain weevil, the mealworm and the bacon beetle, work mischief in the storehouses and barns of mankind in every clime. The North American monarch butterfly migrates annually in vast swarms to Canada, and presses northward until it is stopped by the cold. Within the memory of man it has extended its range over the whole of the Pacific Islands, while competent observers believe that, ere many years have passed, it will become firmly established on the Asiatic continent. Should this happen, the invasion by this insect of all the warmer parts of Asia and Europe, and the whole of Africa, can only be a question of time. In this way have insects contrived to get about in the world.

The range of size covered by insects, although at first less obvious, is scarcely less remarkable than their geographical distribution. A West African Goliath beetle, side by side with our own "seven-spot" ladybird, affords a striking comparison. Yet the ladybird is not, strictly speaking, a very small insect. A family of beetles to which naturalists have given the ponderous name of *Trichopterygidæ* comprises many species which could crawl easily through the eye of a small needle. Again, there is a Brazilian moth with a wing expanse of more than eleven inches from tip to tip; while at the other end of the scale we find moths so small that their beauties—one might almost add their very existence—can only be perceived by the aid of the microscope. According to Sir

Ray Lankester, the smallest insect of all is a water beetle called *Nanosella* which is only one-hundredth part of an inch long. Thus, in point of size, insects occupy an intermediate place among animals. Some are smaller than the largest Protozoa—the living atoms revealed by the microscope in a drop of water; others are larger than the smallest vertebrates, such as shrews and mice.

Egg clusters of Lackey Moth (*Clisiocampa neustria*) on twig

Empty egg-shells of Buff-tip Moth (*Phalera bucephala*) on underside of leaf

Egg capsule of Cockroach (*Blatta orientalis*)

Egg of Parasite of Peacock (*Mallophaga*)

Egg of a "Stick" Insect (*Phasmida*)

Stalked eggs of a "Lacewing Fly" (*Chrysopidæ*)

Eggs of a two-winged Fly (*Diptera*)

(All greatly magnified)

CHAPTER II

THE YOUNG INSECT

Among aphides or plant-lice, the females of the summer generation are viviparous: *i.e.* they give birth to living young. Certain two-winged flies—for example, the blood-sucking forest flies and the dreaded tse-tse flies of the African continent—multiply by producing, one at a time, full-grown grubs which change immediately to pupæ. But such exceptions serve to point the rule that insects, as a class, lay eggs. The eggs of some large beetles differ little in appearance from those of the smaller species of humming-birds; but whereas the eggs of birds are remarkable for the wide range of colour and markings which they display, those of insects vary chiefly in form. Some insects' eggs are quite fantastic. The eggs of lace-wing flies, for example, are supported upon long stalks, the bases of which are glued by the female to a twig or a grass blade. Again, the eggs of the extraordinary walking-stick insects and their kindred are almost always remarkable. Some are like little flasks, while many bear a very close resemblance to the seeds of plants. Each egg is provided with a little cap, or lid, which is pushed up by the young insect when it emerges. Among the more minute eggs of insects, those of butterflies and moths are noteworthy on account of the exquisite sculpturing of their shells. This ornamentation takes the form of a particular pattern in the case of each species; but whether a useful purpose is subserved thereby is open to question. Still more beautiful in their adornment are the eggs of

certain minute parasites (Mallophaga) which live among the feathers of birds.

The number of eggs laid by the individual insect varies greatly according to the species. Some of the solitary bees and wasps lay only a dozen or so. On the other hand, it is estimated that the queen hive-bee, surrounded as she is by a vast army of willing nurses, may lay as many as a million eggs in the course of her career. The methods of egg-laying are equally diverse. Some insects deposit their eggs singly, others in groups or clusters. Each species adopts a characteristic method; while the eggs are almost always laid either upon, or close to, the substance upon which the offspring is destined to feed. Sometimes they are actually inserted into the food substances by means of a special organ, called the ovipositor. Occasionally the eggs of insects are enclosed in a kind of pod or capsule. This is the case with the common cockroach. It lays its eggs in batches of sixteen at a time, each batch being packed in a mahogany-coloured receptacle—eight eggs on one side, eight on the other, in two parallel rows. The mantids, or praying insects, adopt a somewhat similar plan; but their egg-packets usually resemble wild fruits or seed-vessels. Moreover, the mantids always attach them to some object, such as a stone, a twig, or a grass stem; whereas the female cockroach carries about her egg-capsule until she finds a convenient crevice in which to hide it.

A statement is sometimes made to the effect that insects never grow. Obviously this can only be accepted with considerable reserve, for if we compare the egg of any insect with the insect itself, we perceive that an astonishing transformation must intervene to bridge over the difference between the two. The fact is that an adult insect, such as a moth or a beetle, does not grow; but

this is merely because its development is already complete. We may compare the life of an insect to a long hill which ends abruptly in a precipice. When the young insect (usually termed a larva) hatches from the egg, it enters upon a protracted period which it devotes almost exclusively to feeding. Food is the key-note of its being, the hinge upon which its every action turns. Then follows a comparatively brief period of maturity, terminated by the insect's death. The aquatic larva of the well-known may-fly, for example, feeds voraciously for several years; whereas the adult insect takes no food at all, and lives only for a few hours. Its jaws and digestive tract are quite functionless—are reduced, indeed, to mere vestiges. Of course this is an extreme case; yet it serves to emphasize the fact that the life of a typical insect is sharply divided into two periods—one long, the other comparatively short. In a sense, therefore, the young insect and its adult form may be regarded as separate personalities, each charged with distinct duties. The former undertakes the task of storing up food material, while the latter is concerned with courtship and parentage. Let us glance once more at the case of the may-fly. We see a long larval life entirely devoted to the production of an ephemeral being, incapable of feeding, whose one and only duty is to reproduce its kind. Indeed, the final winged state of the may-fly might long ago have fallen into obsolescence were it not for the fact that in this state alone is reproduction possible.

Among the more primitive insects the newly-hatched larva is practically a miniature copy of its parents. The baby cockroach, for instance, has an unmistakable family likeness from the first, although it is almost colourless and quite destitute of wings. Very soon after hatching it casts its skin for the first time. A

second moult occurs about a month later, and a third one at the end of the first year. This business of skin-changing is gone through periodically by all growing insects. It probably coincides with important physiological processes, but men of science are still unable to explain its full significance. We may discard, however, the old theory that moulting is merely an aid to expansion, for the sufficient reason that the soft parts of an insect's skin can, if necessary, be stretched to an enormous extent. An egg-laying queen of the so-called warlike white ants, for example, may have an abdomen two thousand times more bulky than the rest of her body, and this amazing corpulency is attained without a single moult. Again, certain Mexican ants are able to transform themselves into temporary honey-pots. They consume vast quantities of nectar until their bodies become enormously distended, and then dole out the sweet food, drop by drop, to hungry members of their community. The ant's ability to perform this singular office is entirely due to the elasticity of its skin between the hard abdominal plates. Such feats indicate that periodic skin-changing is not an indispensable accompaniment to increasing bulk.

There is still some doubt as to the exact time which the young cockroach takes to reach maturity. It is sometimes said that the insect does not become adult until the fourth year of its life; but when one considers how rapidly its numbers increase under favourable conditions, one is inclined to doubt this statement. Perhaps the period of infancy varies with the abundance or scarcity of suitable food, or with the mean temperature of the particular basement or store in which a clan of cockroaches has made its home. Be this as it may, the important fact remains that the wings of the cockroach

Plate IV

1

2

3

4

Successive stages in the transformation, from Caterpillar to Chrysalis, of the Silver-washed Fritillary Butterfly (*Argynnis paphia*)

are acquired gradually as growth proceeds, appearing first as buds or rudiments from the second and third segments of the thorax, and attaining their complete development only after the final moult, when the insect becomes adult. In the common cockroach the male alone possesses functional wings, although in certain nearly related species both sexes are capable of flight.

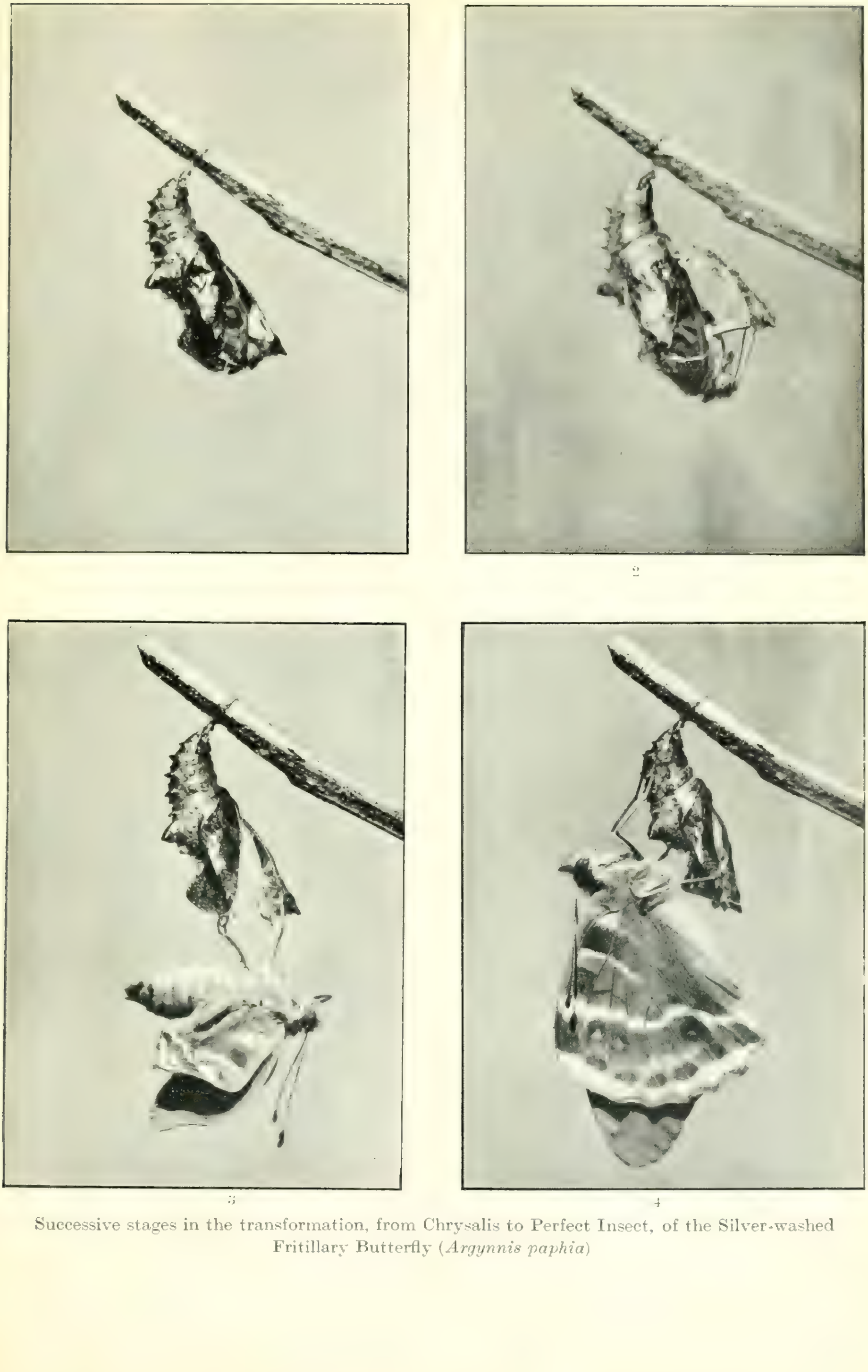
The manner of growth exemplified in the life-history of the cockroach obtains among many other insects, such as crickets, grasshoppers, and earwigs, while there is good reason for thinking that the ancestors of all insects reached maturity in this way. At the present day, however, a vast number of insects undergo a much more elaborate process of development. Their lives are mapped out into three well-marked stages. Beetles, bees, wasps, ants, and butterflies are among the insects which undergo these transformations. Everyone knows, for example, that the young butterfly—the caterpillar as we call it—differs in a thousand ways from its parents. There is no family likeness whatever. Moreover, when a caterpillar has consumed its allotted share of food, it does not immediately become adult, but enters upon a more or less protracted period of fasting and repose, when we call it a chrysalis.

Let us examine a specific instance. When the caterpillar of the silver-washed fritillary butterfly (*Argynnis paphia*) has eaten its fill of violet leaves, it repairs to the stem of some low bush, often a bramble, and there spins a small pad of silk. This pad it grasps with its hindmost pair of prolegs, and then lowers itself very deliberately until it hangs head downwards. It remains thus, motionless, for some hours. Muscular contractions are then noticeable, the skin splits dorsally, and is gradually worked towards the tail by the efforts of the caterpillar, which is now changing to a chrysalis before our eyes.

The manner in which the chrysalis becomes attached to the silken pad is rather complex, and not at all easy to observe. The chrysalis appears to grasp the old caterpillar skin, which still retains its hold on the support, between two of its abdominal segments. It then withdraws its tail, which terminates in a many-hooked process called the cremaster, and thrusts this upwards against the silken pad. The hooks of the cremaster at once become entangled, and the chrysalis deliberately strengthens the hold thus gained by vigorously whirling and twisting its body. Incidentally, the now useless caterpillar skin is dislodged and falls to the ground. At first the chrysalis is elongate and soft, but it rapidly contracts, hardens, and assumes its characteristic form and colouring. Some three weeks later its skin breaks open, and the butterfly emerges, limp and comparatively helpless.

It is important to realise that the butterfly, when it escapes from the chrysalis, is in every way perfect, with the form and size of maturity, save for the wings and the abdomen. The former are small, pad-like organs, while the latter is swollen with the fluids which will flow into and fill out the wings. This influx of fluids is exceedingly rapid. The wings grow steadily as we watch until they attain their full size. The principle which underlies this marvellous transformation may be described briefly as follows: The expansion of the wings is due directly to blood-pressure—the blood being forced from the body to the wings chiefly by the contractions of the abdominal muscles. In the newly-emerged insect the two membranes of which the wing is formed are soft and corrugated, and expansion consists in the flattening out of the folds under pressure of the incoming fluids. We see, therefore, that the wing is virtually a sac, which would tend to expand into a balloon-shaped bag were it not for numerous

Plate V



Successive stages in the transformation, from Chrysalis to Perfect Insect, of the Silver-washed Fritillary Butterfly (*Argynnis paphia*)

internal ligaments that hold the membranes together. We may illustrate this fairly correctly by blowing out a kid glove—though the glove, of course, has no connective threads within to prevent it assuming the balloon shape. The butterfly remains hanging from the empty chrysalis case until its wings are sufficiently hardened for flight. Then it soars away into the sunlight—an exquisite being, differing in a thousand ways from its caterpillar form.

The changes which mark the growth of an insect from the egg to the adult are termed its "metamorphosis." When these changes are gradual and not very distinct, as in the case of the cockroach, the insect is said to undergo *incomplete* metamorphosis, and the word "nymph" is often used to describe its immature state. But when the stages of growth are strongly marked, as in the case of a butterfly, the metamorphosis is said to be *complete*, while the insect is known first as a larva or caterpillar, then as a pupa or chrysalis, ere it becomes adult.

Metamorphosis is by no means confined to insects. We may witness the phenomenon, at least to a limited extent, in the development of all animals, although strictly speaking the term is used only to describe those form-changes which follow birth or hatching. When a chick breaks through the egg-shell, it has already lived for many days; and for its nourishment during this period of early development the yolk is provided. In almost all such cases—*i.e.* when ample yolk provision is made for pre-birth development—the young animal is born or hatched in a form closely resembling that of its parents. The form-changes which take place as it grows to maturity are so slight that we can scarcely speak of them as a metamorphosis. But vast numbers of animals, especially in the sea, lay eggs which are meagrely provisioned with yolk, and hatching takes place, of necessity, at a very

early stage of development. The young are turned out in an unfinished state, so to speak, and are left to shift for themselves. Starfishes, oysters, crabs, and many other marine creatures start life in this way. The struggle for existence is more fiercely contested in the sea than upon the land; infant mortality is rife; and as an offset to this ocean dwellers produce multitudinous young of which only a few are destined to survive. Clearly a crab, which lays many thousands of eggs, cannot provision each of these with yolk as liberally as an animal which lays, perhaps, only ten or a dozen eggs. Thus young crabs hatch prematurely. They issue from the egg in a form very unlike that of their parents, and pass through an elaborate metamorphosis ere they reach the adult state.

Naturalists were at one time inclined to regard the larva of an insect simply as a prematurely hatched embryo approximating to the young form of a crab or an oyster. But more perfect knowledge has led them to adopt a different view of the case. It is now known that the eggs of insects, in common with those of almost all land animals, are plentifully provisioned with yolk, so that the need for premature hatching does not obtain. Moreover, we have already seen that metamorphosis is complete only among the more highly specialised forms of insect life, while among primitive insects, like the cockroach, it is slight. These facts suggest that metamorphosis among insects is not a mere offset to infant mortality, but that it is the outcome of successful conquest and established supremacy. In other words, the transformations through which a young insect passes cannot be regarded merely as phases in its development, but as elaborate adaptations to its changing conditions of life.

How can complete metamorphosis among insects be explained? It is probably due in large measure to the

diverse ways of feeding which the individual insect has been able to adopt, in successive periods of its existence, owing to the fact that it becomes winged after its final moult. The habits of the more primitive insects, such as the cockroach, are nearly the same throughout life. Thus, external circumstances affect both the young and the parent insect in a similar manner, and there is little difference between the one and the other. But as we follow the scale upward, we find that the adult insect tends to become more and more unlike its immature form in proportion as it makes use of its wings to explore new territories, and to tap fresh sources of food-supply. Moreover, the change in the character of the food frequently necessitates a profound modification of the mouth-parts—as in the case of the biting caterpillar which ultimately becomes a butterfly destined to suck sweet juices through a trunk-like organ. A transformation so complete must necessarily involve deep-seated physical processes: to quote Lord Avebury, it "could hardly take place while the insect was growing fast, and consequently feeding voraciously; nor, if the change could be thus effected, would the mouth, in its intermediate stages, be in any way fitted for biting and chewing leaves. The same reasoning applies also to the digestive organs. Hence the caterpillar undergoes little, if any, change, except in size, and the metamorphosis is concentrated, so to say, into the last two moults. The changes then become so rapid and extensive that the intermediate period is necessarily one of quiescence."

We see, therefore, that the resting chrysalis or pupal stage is an indispensable connecting link, among the higher insects, between two totally distinct phases of life. Successive steps in the evolution of metamorphosis may be traced through the various groups, or orders, into which

insects are divided. The simplest insects, typified by the wingless "silver-fishes" of our larders, undergo no metamorphosis. They merely increase in size as they grow from youth to maturity. Among the cockroaches and their allies an incomplete metamorphosis obtains, marked by the acquisition of wings after the final moult. But as the environment and food habits of the individual remain practically unchanged throughout life, the development of wings scarcely affects its activities, and there is little difference between the young and the adult forms. We may contrast this with the case of the dragon-fly, of which the nymph bears little or no resemblance to its parent. Each obtains its livelihood in a different way, and among distinct surroundings—the one capturing its prey in the water, the other in the air. The change of habit is not so great, however, as to render necessary an intermediate period of quiescence. Yet it is possible to regard the dragon-fly nymph, in the last stage of its development, as an incipient pupa. If it were to remain inactive for a few hours or days prior to its final transformation, it would, indeed, foreshadow the true pupal state. Something of the kind actually occurs among the cicads. These insects are very abundant in tropical countries, but only one species has been found in Britain. The young nymphs have large digging fore-legs, with which they burrow in the ground. Their mouth-parts are formed for sucking, and they obtain food from the soil humus, as well as from the roots of plants. The perfect insect, on the other hand, has large and powerful wings, and sucks the juices of trees and shrubs. In the case of the American cicada, known as the "seventeen-year locust," the nymph remains underground for thirteen or seventeen years—a life-spell greatly in excess of that enjoyed by any other insect. The point which I desire to emphasize, however, is this:

that just before the cicada nymph is ready to assume the winged state, it ascends to the surface of the ground, and there often constructs a pillar-like cell of mud in which it passively awaits its final transformation. This appears to be a purely voluntary act, for the faculties of the insect remain quite unimpaired. Indeed, many individuals never build earth-cells at all, but continue their underground life until the last moment, and climb up the trunk of a tree just before the skin splits down the back, allowing the adult insect to issue forth.

The case of the cicada is especially interesting, because we seem to see in it the dawning of the pupa habit, though no pupal form is assumed. Another step in the evolution of metamorphosis is exemplified by the tiny black insects known as thrips, which are often so numerous in flowers. In its last stage the thrips nymph, though it moves, is sluggish, while its limbs are enveloped in a membrane and its wings enclosed in sheaths. Finally, among the scale insects, we come upon a kind of connecting link between incomplete and complete metamorphosis. These insects get their name from the fact that many of the species exude a waxy secretion from their bodies which hardens into a protective scale, or shell. They have sucking mouth-parts, and many of them are very injurious to vegetation. Perhaps the most familiar species in England is the so-called mussel scale, or bark louse, which may often be found in myriads upon the stems and branches of apple trees in neglected orchards. While the female insects, which are wingless and strangely degraded in form, undergo a typically incomplete metamorphosis, the winged and active males pass the last stage of their development in a passive, pupa-like condition, enclosed in a waxy cocoon.

Because the life-cycle of any one insect is really an

epitome of its ancestral history, we are justified in the belief that complete metamorphosis became established through an evolutionary process such as the above facts suggest—a process which has culminated in the astonishing transformations of the higher insects. Let us recapitulate the points of the case. The function of nutrition is relegated to the young insect, that of reproduction to the adult. In the course of ages the gap between the two life-stages has increased, the young insect and its perfect form becoming adapted to very different environments. Finally, the gap has grown so wide that the revolutionary changes which must be effected to bridge it over necessitate an intermediate period of quiescence—the pupal state.

The term *pupa*—a Latin word signifying a doll or mummy—is reserved strictly to describe the resting stage of those insects which undergo complete metamorphosis, the alternative term chrysalis (from the Greek *chrysos*, gold) being often applied to the pupæ of butterflies on account of the shining, metal-like areas for which many of them are remarkable. The pupæ of most butterflies and moths, and of some two-winged flies, are obtect, or covered, the appendages of the body being compactly united. But among beetles, caddis-flies, ants, bees, wasps, and other insects, the pupa reveals many of the characters of the perfect insect. The legs, though pressed closely to the body, are not intimately fused with it, while the wing rudiments hang like flaps from the segments of the thorax. Such pupæ are said to be "free." Finally, in the case of most two-winged flies, the last larval skin, instead of being worked off by the usual process, is retained. It contracts and hardens to form a kind of protective case, called the puparium, within which the pupa lies.

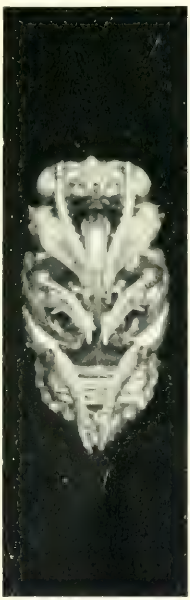
Although the pupa state is typically one of quiescence,

PLATE VI

Pupa of Swallow-tail Butterfly (*Papilio machaon*): greatly magnified

Pupa of Brimstone Butterfly (*Gonopteryx rhamni*): greatly magnified

Pupa of Convolvulus Hawk-moth (*Sphinx convolvuli*)



Pupa of a Bee (*Megachile*): greatly magnified

Cocoon of Silkworm Moth (*Bombyx mori*)

certain pupæ retain limited powers of movement and locomotion. Subterranean pupæ wriggle their way to the surface of the soil, often by the aid of spines which arise from the abdominal segments. The grotesquely shaped pupa of a gnat, though it usually floats passively at the surface of the water, dives with the utmost promptitude and alertness to escape danger. The pupa of a snake-fly becomes active just prior to its final moult and creeps from under the bark where it has lain hidden. The most remarkable motile pupæ, however, are found among the well-known caddis-flies. The full-grown larva, or "worm," turns to a pupa within its case; but just before the final transformation, the pupa bites its way out and swims to the surface of the water, using its middle pair of legs, which are developed like oars for the purpose. The skin of the pupa then splits down the back, and the perfect caddis-fly emerges.

Insects usually undergo no further moult after they attain the winged state. May-flies, however, furnish a remarkable exception to this rule. When the nymph is full grown, it ascends a plant stem to the surface of the water, where its skin splits, and a winged insect emerges. This process occupies a very short time, it may be only a few seconds. The winged form, however, is known as a sub-imago. It is still completely enveloped in a delicate skin, which is thrown off either at once, or after an interval of several hours, and the insect is then in its perfect state. The cast skins, looking like ghosts of departed may-flies, may often be seen in myriads attached to fences, tree trunks, and vegetation in the vicinity of streams and rivers.

So far we have considered the young insect mainly in its capacity as a forerunner of the adult. But we have seen that it lives a life apart, and is chiefly concerned with

its own immediate needs. Thus, it is scarcely surprising that the appearance of young insects varies greatly in accordance with their customary surroundings and food-habits. Nevertheless, most young insects can be referred to one of two groups. The first of these comprises nymphs and larvæ which, on account of their general resemblance to a lowly insect called *Campodea* (it is a near relative of the well-known "silver-fish"), are termed campodeiform. Young insects of this pattern have well-developed legs and powerful jaws. They are remarkably active and wide-awake, while their skin is commonly more or less hardened, or chitinised, after the manner of the adult. The immature forms of dragon-flies, may-flies, lacewing-flies, and many beetles are of this kind. They may be contrasted with the larvæ of many other beetles, of moths, of flies, and of bees and wasps, which conform more or less closely to a caterpillar-like type. Such larvæ are termed eruciform—*eruca* being the Latin word for caterpillar. They are characterised by their cylindrical, soft-skinned bodies, reduced mouth-parts and feeble legs. Their habits are usually sedentary, and their sense-organs are correspondingly reduced. In extreme cases the larva becomes an inert and footless maggot.

This division of young insects into two groups, however, cannot be rigidly maintained. Among beetles, for example, an almost complete transition can be traced from one to the other. Moreover, in a few instances both forms of larva occur in the life-cycle of one species. This is so in the case of the oil beetles—those rather repulsive insects which are often abundant among herbage in the early summer. The newly hatched larva is campodeiform. It lives an active life upon plants and flowers, without feeding, until it manages to spring upon a humble-bee. In this way it is carried to the bee's nest, where it first

eats the eggs. It then casts its skin, and is transformed into a soft, short-legged grub, which feeds upon the honey stored by its hosts; while after its third moult it becomes an eruciform maggot, with functionless mouth-parts and atrophied legs, not unlike the bee larvæ whose food it purloins.

Cases of this kind are termed hypermetamorphosis, *i.e.* something over and above the form-changes which metamorphosis commonly involves. They throw a light upon the evolution of young insects in general. We perceive that the active, campodeiform larva is the primitive type, because in hypermetamorphosis it invariably precedes the eruciform type, the latter being correlated with congenial surroundings and a plentiful food-supply. We are thus able to explain what, at first sight, seems a paradox, namely, that while the larvæ of the less highly developed insects are active and capable, those of the more highly developed species are inert and grub-like.

The chief point to bear in mind is this: that the form of the young insect is due, either directly or indirectly, to the manner in which its food is obtained—directly in the case of the mouth-parts, legs, and sense-organs; indirectly, where protective adaptations are concerned. The predaceous nymph of the dragon-fly, or the larva of a ground beetle, is wholly dependent for food upon its physical endowments and powers of sensation, while it is inevitably exposed to many risks in the course of its career. A caterpillar, on the other hand, gets its food with little effort, and is in measure protected by its surroundings. The same remark applies with greater force to the maggot of a flesh-fly which is literally immured in an abundance of food, and to the grub of a bee or wasp which is provided with food by its parents or by the adult members of its community. The principle is really one of degene-

ration, or more correctly of simplification, induced by a congenial, well-fed condition of life. Its operation is familiar in the case of parasites. Indeed, the parasitic larva of an insect differs little from the maggot of a flesh-fly or the grub of a wasp. In each instance the simplification of the offspring is due to the highly specialised instincts of the parent, through the agency of which abundant food and ample protection are assured.

CHAPTER III

THE ORIGIN OF INSECTS

That the race of insects is inconceivably ancient cannot be doubted. "We often take the mountains as emblems of age" (I quote Professor Carpenter) "and speak of the 'everlasting hills.' The most advanced orders of insects are older than the chalk of the southern English downs, while the early winged insects flitted by the shores of the lakes wherein the grits and sandstones of the Kerry Reeks gathered fragment by fragment. For the primitive wingless insects we must look at least to the time when by accumulation of coral, and the ash and lava of old volcanoes, the rocks of Snowdon were being slowly formed on the bed of the Primary sea. . . . We walk over the hills rousing the bee from the flower, or the dragon-fly from the rushes. The life of each individual insect lasts but for a few days, or months, or years. Yet these creatures are the latest links in a long chain of life which reaches back to a time before the mountain whereon they dwell was brought forth. To unobservant eyes the landscape seems enduring, but study of its features shows that it changes from age to age, changes even more rapidly than the insect-types which adorn it."

There must have been a time, however, when insects, as such, first came into being. How did these primitive insects originate, and what were they like? The difficulties which beset such an inquiry are too obvious to call for emphasis, yet they are not so great as to preclude all possibility of conjecture. The conception that living

things, in all their endless variety, are the outcome of special creation, has given place to the more plausible theory that the existing species of plants and animals were derived, through a slow process of modification, from more simple forms. Many of the older naturalists believed that this relationship of living things was in the nature of a progressive scale, like the rounds of a ladder. They put the simplest plants and animals at the base, and added the remaining groups, step by step, in the order of their increasing complexity. But advancing science has shown that the true affinity of living things cannot thus be expressed. On the contrary, a careful survey of all existing species, and of extinct species which are known to us as fossils, suggests that their relationship may be most fittingly compared to the branching of a tree towering upwards from the root-stock of life. Each of the great branches is termed a phylum, or tribe. One, in the case of animals, comprises the vertebrates, another the cuttles and shell-fishes, and so on; while the phylum with which we are specially concerned includes the annulate or ringed worms, wheel animalcules, spiders, crabs, centipedes and insects.

We must realise that the creatures comprised in each tribe, or phylum, are all, so to say, variants of one root idea. In other words, they are all built up from a single plan, simple in itself, but capable of endless modification and improvement. This plan, in the case of the phylum to which insects belong, consists of a head-lobe followed by a series of nearly identical rings, or segments, each enclosing a portion of the body-cavity, with its share of the nerve-cord, the digestive tract and the main blood-vessels. Each segment also carries a pair of external appendages, or limbs, symmetrically arranged, with their necessary motor muscles. Hence these creatures are

known collectively as Appendiculata. They are divided into three sections: (1) the marine worms, earthworms and leeches, called Chætopoda, or "bristle-footed"; (2) the wheel animalcules, or Rotifera; (3) the "foot-jawed" animals, or Gnathopoda, including insects.

According to Sir Ray Lankester, "the Gnathopoda have been derived from ancestors of the lower grade represented by the Chætopoda. They have the surface of the body covered by a hard, horny skin (except in Peripatus and immature grubs), and the legs or appendages divided into hard, movable joints, whence they are often called Arthropoda (*i.e.* with jointed feet). They are definitely characterised by having one or several of the pairs of limbs, which belong to the rings behind the head, turned towards the middle line, so that their hard, horny projections can be made by the muscles to meet one another, and nip any foreign body. These modified legs are called 'jaws,' or 'foot-jaws,' and are never found in the Chætopoda. They are easily seen in the stag-beetle and the wasp. Another leading feature in which the Gnathopoda (also called the Arthropoda) have developed away from and to a higher level than the Chætopoda is in having from one to three of the series of rings which immediately follow the simple head-lobe of Chætopods, incorporated and completely fused with it to form the 'head,' by means of the backward shifting of the mouth. These new head segments or rings, which have, as it were, 'slipped' in front of the mouth, are distinguishable in very early growth, but not in the adult. They have their limbs modified as eyes or as long tactile organs (antennæ), or rarely as nippers."

Gnathopoda, as above distinguished, are divided into six great groups, called classes. The first class includes the strange caterpillar-like animal Peripatus and its con-

geners, the second the millipedes and pill-millipedes. Both these classes stand apart from, and are simpler than, the others. The members of each have only one body ring added to the head, and only one pair of "foot-jaws." The appearance of millipedes and their allies (termed Diplopoda because they have two pairs of legs on each segment of the body) must be familiar to the reader, but Peripatus and its kindred, which constitute the class Peripatoidea, call for a brief description. Professor Adam Sedgwick tells us that these curious animals live beneath the bark of rotten tree stumps, in the crevices of rocks, and beneath stones in South Africa, New Zealand, Australia, South America and the West Indies. They differ from all other Gnathopods in possessing certain worm-like peculiarities, notably in the softness and pliability of their skin. Nevertheless, their appearance is distinctly pleasing. "Peripatus" (says Professor Sedgwick), "though a lowly animal, and of remarkable sluggishness, with but slight development of the higher organs of sense, with eyes the only function of which is to enable it to avoid the light—though related to those animals most repulsive to the æsthetic sense of man, animals which crawl upon their bellies and spit at, or poison, their prey—is yet, strange to say, an animal of striking beauty. The exquisite sensitiveness and constantly changing form of the antennæ, the well-rounded plump body, the eyes set like small diamonds on the side of the head, the delicate feet, and, above all, the rich colouring and velvety texture of the skin, all combine to give these animals an aspect of quite exceptional beauty."

Two other classes (or shoots from the main stem of foot-jawed animals) are called respectively the Arachnida and the Crustacea. The former class includes, among less familiar creatures, the king crabs, spiders, scorpions,

ticks, and mites; the latter, the water-fleas, barnacles, true wood-lice, and animals of the crab and lobster kind. Sir Ray Lankester tells us that the Arachnida have two rings or segments, in front of the mouth, added from the body to the primitive head; whilst the Crustacea (also the two remaining Gnathopod classes) have three such additional, or "pre-oral," head-segments. The probable derivation of the two remaining classes—viz. the centipedes or Chilopoda (so-called because the lower lip is formed by a pair of feet) and the insects or Hexapoda ("six-footed")—is still debated; but strong evidence exists in support of the view that they branched off from the Crustaceans. At least we are justified in asserting that insects have descended from lowly Gnathopod ancestors. We have already seen that the dominant characteristic of these creatures is the modification of certain limbs to play the part of jaws, and that the number of these foot-jaws varies. The higher Crustaceans have a group of them (as many as six pairs) devoted to the service of the mouth, while centipedes and insects have only three pairs. Moreover, the total number of legs is subject to great variation in the different classes. Peripatus, millipedes, and centipedes have very numerous legs, and so have the primitive Arachnids and Crustaceans. But among the higher representatives of the latter classes, and in all insects, many pairs of legs are suppressed; so that while a crab has five pairs of walking legs, and a spider has four pairs, an insect has only three pairs. Furthermore, with this reduction of legs, a more or less definite grouping and fusion of the segments is noticeable; until, in the case of insects, we find a constant division of the body into three areas—viz. the head, the thorax, and the abdomen. As to the precise number of primitive body rings which go to make up a typical insect, naturalists are by no means agreed;

but there is much evidence to support the view that the head is made up of six segments (three in front of, and three behind, the mouth), the thorax of three, and the abdomen of twelve—twenty-one segments in all.

The origin of insects' wings, which spring from the second and third thoracic segments, is also a debated point; but the fact that insects possess these organs, in combination with their other specialised endowments, places them indubitably at the head of the foot-jawed class, and consequently of the whole Appendiculate phylum. Yet we must not infer that each and every insect is more highly specialised than (for example) a crab or a spider. "A shoot arising low down on a branch" (says Professor Carpenter) "may send out twigs which overtop the lower twigs of a shoot whose origin is higher." Thus, while such an insect as a fly or a wasp represents the "last word" in the evolution of ring-planned, foot-jawed creatures, many of its lowly kindred have by no means attained to this high level of perfection. Among animals that are not insects, those which approach most nearly to the insect type are certain centipede-like creatures which belong to a genus called *Scolopendrella.* They live in damp earth, and similar concealed situations. They are small and fragile, with a pair of antennæ, three pairs of foot-jaws, and an evenly segmented body with fourteen pairs of limbs. This, of course, is eleven pairs in excess of those possessed by insects; but the most lowly of all living insects, the silver-fishes and their allies, actually reveal the vestiges of paired limbs on several of the abdominal segments, while the presence of others is indicated by caudal appendages termed cercopods.

We thus get some indication of the genealogy of insects. But how were the innumerable changes from

lower to higher grades effected, and by what means did insects come to differ from one another? The answer to this question is believed to lie with a great underlying law, or principle, known as *natural selection.* In order to understand its working we must recognise the fact that while an animal resembles its parents in the main, it nevertheless differs from them in more or less noticeable details. Thus an ordinary dun cow may give birth to a white calf, or (in an extreme case) to a calf with six legs. Such variations may be useful or not useful, transmissible or not transmissible; while the transmissible variations, whether useful or the reverse, tend to be handed down from parent to offspring through successive generations. Nevertheless, we do not find that animals are encumbered with meaningless or harmful characteristics. In some way the useless variations are stamped out and disappear. How is this accomplished? We must remember, in the first place, that any one species of plant or animal, were its multiplication unchecked, would soon cover the whole earth. Professor Huxley computed that the progeny of a single aphid would, in ten generations, "contain more ponderable substance than five hundred millions of stout men; that is, more than the whole population of China." Yet this kind of thing does not happen, because the vast majority of plants and animals meet destruction in early life; so that while an insect may lay a hundred eggs, the individuals of the species are not thereby increased a hundredfold, but remain approximately unchanged from year to year. The survival or destruction of the individual is due, at least in large measure, to the principle of natural selection. Those individuals survive which have inherited the most favourable variations, whether of structure, instinct, or habit, while those which are less favourably endowed perish. Thus we speak of the

"struggle for existence" which goes on among all living things, and of the "survival of the fittest."

There is much in the lives of insects that will cause us to ponder this law of natural selection, and we shall do well to grasp its exact import. Little evidence exists to support the view that characteristics acquired during the life-spell of an individual, as distinct from those which come to it as the result of inborn (or congenital) variation, are transmitted from parent to offspring. "On this view" (says Professor Carpenter) "the broad fore-limbs of earth-burrowing insects like the mole-cricket are the direct result of a digging habit persevered in through many generations, while the wingless condition of many female and parasitic insects is simply due to their ancestors having given up flying. It is hardly necessary to point out how differently the natural selection theory accounts for such facts as these. According to its advocates no amount of the most vigorous digging on the part of a primitive cricket would avail to provide its descendants with broad fore-legs; these organs are believed to have been slowly specialised through a long series of generations of crickets, which were adopting the burrowing habit, through the selection in each generation of those individuals best adapted for burrowing, that is, those which possessed the broadest and strongest fore-legs, the broadening not being an acquired but a congenital character. And there is no doubt whatever that congenital characters are transmissible. In the same way it would be believed that the loss of wings in the insects mentioned above being, for some reason, actually beneficial to the species, individuals with the smallest wings were selected through numerous generations until those organs were almost or entirely lost."

We must not suppose, however, that the perpetuation

of external characters necessarily implies their direct usefulness to the species concerned. External characters, useless in themselves, may be mysteriously bound up with important chemical or physiological conditions. For example, Darwin states that male white cats with blue eyes are deaf; and Sir Ray Lankester remarks that "if deafness were ever an advantage (a difficult thing to imagine), you would get a species of cat with white hair and blue eyes, and be led to distinguish the species by those characters, not by the real cause of survival—namely deafness." Thus, obvious but useless characters may be established by natural selection because of their correlation with others that are useful but obscure, and there can be little doubt that the peculiarities of many species can only be satisfactorily explained in this way.

We have still to see how varieties, established through the agency of natural selection, may be consolidated into species. In order to make this clear, I cannot do better than repeat an instance cited by Professor Carpenter, especially as it concerns the well-known brown argus butterfly (*Polyommatus astrarche*). This insect frequents sunny hillsides in the south of England in June and again in August. The upper surface of the wings is dark sepia-brown in colour, while there is a black spot in the centre of each fore-wing. Further, within the margin of each fore-wing there is a row of orange spots. On the underside, the ground colour of the wings is light greyish fawn, while around the margins, inside a series of white lunules and black specks, there are rows of orange spots surrounded by white rings—"eye-spots" as they are called.

As we travel northward we find that the brown argus butterfly is much rarer in the English midlands than in the south; but in many places in the northern counties it again becomes common. We find, however, that most

of the specimens from these localities exhibit characters which, in the southern counties, are rarely seen. The black spots in the centre of the fore-wings are smaller, and surrounded by white; the orange marginal spots are indistinct, while the black spots on the underside of the wings are small, or altogether wanting. At this stage the butterfly is known popularly as the Castle Eden or Durham argus, and to men of science as the variety *salmacis*. If we go still farther northward, to the Clyde in the west and to Aberdeen in the east, we shall find that these characters are intensified, and that the southern English form of the butterfly does not occur at all. In these Scotch forms the central spot in the fore-wing is pure white, the orange marginal spots are absent (in a few specimens they are dimly discernible), while the black spots on the underside of the wings have entirely disappeared. We have now the Scotch brown argus, the variety *artaxerxes* of science.

"These typical Scotch insects" (writes Professor Carpenter) "differ so markedly from those found in the south of England that they were formerly believed to belong to a distinct kind. This opinion received confirmation in the fact that while the southern form has two life-cycles in the year (the June butterflies laying eggs which develop into a fresh generation of butterflies in August, the offspring of these surviving the winter as caterpillars), the northern form has but a single brood (the butterflies appearing in June and July, and the caterpillars hatched from their eggs not pupating until the following spring). But the study of the insect in the north of England (especially in Durham) has shown, as we have seen, that both the Scotch and southern forms occur together, and that every intermediate link between them can be found. Moreover, all these diverse forms can be reared from the same

batch of eggs. No doubt remains therefore that the Scotch and southern insects are not distinct kinds, but *varieties* of one kind. And instead of writing the name of the Scotch insect as formerly, *Polyommatus artaxerxes*, we write *Polyommatus astrarche* var. *artaxerxes*, the term *variety* being applied where one form differs from another to a recognisable extent, while, nevertheless, intermediate forms are known to bridge over the gap between the two, and both can be derived from the same parents. . . . Now it is quite conceivable that the area where the typical *astrarche* and the variety *artaxerxes* overlap might at some future time be submerged beneath the sea, and so all the connecting links might become exterminated. Or the same result might be brought about without any such serious geographical change, since the dying out of several species over wide areas has been noticed in recent years. The form *artaxerxes* inhabits the western part of Ireland, in which country the typical *astrarche* is not known to occur at all. The Irish *artaxerxes*, then, is isolated from the English *astrarche* by a sea-channel, and intermediate forms are unknown. And if, as may happen in the future, the Scottish *artaxerxes* should become similarly isolated and the connecting links should die out, no hesitation would be felt in considering the two insects as distinct species."

We see, therefore, that a species is, in its origin, a variety which has become permanently estranged from its near relations. This estrangement is usually so marked that the individuals of one species will not—in the vast majority of cases they cannot—interbreed with those of another species. Yet it is often impossible to draw a definite line between a species and a variety; while a species, although it may persist over long periods of time, is in no sense immutable. In the course of ages it may

be split up, so to speak, into varieties, and these in their turn may become established as new species.

Species which display a close similarity of structure are grouped by systematic naturalists to form a *genus*. Genera are combined as *families* in accordance with the leading characteristics of their members. Families are massed as *orders*, into which the whole *class* of insects is divided.

CHAPTER IV

MOUTH-PARTS, WINGS, AND LEGS

Let us imagine for a moment that we are looking into the face of a cockroach. The smooth, rounded forehead, the large eyes, and the bases of the antennæ are all prominent features; but the mouth—*i.e.* the opening which leads to the gullet—is hidden by a hard plate which is hinged to the solid armour of the head. This is the upper lip, or *labrum*. Behind it are the three pairs of mouth-parts which were derived from the primitive foot-jaws. First come the *mandibles*, which play the chief part in tearing and biting food. Then another pair of jaws, called *maxillæ*, less powerful than the mandibles, but highly sensitive. Each maxilla is made up of four segments. There is a small basal piece, the *cardo*, attached to the framework of the head. To this a larger vertical piece, the *stipes*, is jointed. It carries a feeler, or *palpus;* also, at its lower extremity, the *lacinia* or blade—the cutting tool of the maxilla, as it were—with its sheath, or *galea*. The maxillæ, indeed, are well equipped for examining food, holding it, and passing suitable fragments towards the gullet. In the case of most biting insects, they act like a pair of dexterous hands set just under the mouth. Moreover, they are backed by a smaller pair of similarly jointed jaws, called the *second maxillæ*, which are also furnished with palpi. The basal segments of this third and last pair of jaws are fused together so as to form one plate-like structure; thus the second maxillæ are often spoken of by naturalists as if they were a single organ,

and are then called the lower lip, or *labium*. All three pairs of modified foot-jaws are hinged to the head, and hang in a kind of semicircle behind the labrum. In motion they work from side to side, like pairs of pincers held vertically, and not from below upwards like our own jaws. When not in use they are all packed closely together, and completely cover the mouth.

On the inner, or front, side of the labium (or second maxillæ) there is a fold in the skin of the mouth which is known as the *lingua*, or tongue. In the cockroach and many other biting insects the tongue is an insignificant member, but among certain of the higher insects it becomes greatly changed, and is vested with important duties. At its base the ducts of the salivary glands open.

This description of the mouth-parts of a cockroach will be found to apply, in the main, to all mandibulate or biting insects; but many insects feed chiefly or entirely by suction. Such an insect is the hive-bee. Its mandibles are small and relatively unimportant. They are used chiefly for kneading and cutting wax when comb-building is in progress. The blades of the first maxillæ are long and broad, forming flexible piercers, their sheaths having disappeared, while their palpi are greatly reduced. But the second maxillæ—which are intimately fused to form a kind of elongate plate beneath the mouth—carry long, hairy palpi which serve as feelers. Finally, the tongue has become a long grooved organ, adapted for licking and sucking, which terminates in a small, concave "spoon." The mouth-parts of the bee, excepting the mandibles, are often spoken of collectively as the insect's "tongue," because they can be fitted closely together to perform the office of one elaborate sucking organ. So far as is known, the tongue proper is alone employed when small quantities of fluid are being taken up, but in the presence of abun-

dant nectar the whole suctorial mechanism is brought into play.

A butterfly or a moth—the death's head moth, for example—is equipped with sucking mouth-parts which contrast strongly with those of the bee. Its mandibles are so much reduced as to be practically non-existent. The first maxillæ, however, are very conspicuous. They—or as some authorities believe, their galeæ—are greatly lengthened, grooved inwardly, and united by their edges to form a proboscis or trunk, by means of which fluids can be drawn into the mouth. The maxillary palpi are very small; in some species they are altogether wanting. But those of the second maxillæ are well developed, and stand up in front of the head—the second maxillæ themselves being greatly reduced and quite functionless. In the diagram on Plate IX, the reader must not mistake the space between the eyes of the moth for its mouth. This is merely a depression within which the proboscis, when not in use, lies coiled up like a watch spring. The mouth opens at the base of the proboscis, by which it is hidden.

Among such insects as bugs, cicadas, and aphides the mouth-parts are adapted for puncturing the skins of plants or animals, and for pumping up the sap or blood. Both the mandibles and the first maxillæ are produced at their extremities into long, needle-like processes. These lie normally within a kind of grooved sheath, formed by the labium (second maxillæ). Within this sheath the needles work up and down, and from its tip they are plunged into the organism which is attacked. The juice, or blood, flows up between the needles by capillary attraction, and is sucked into the insect's mouth.

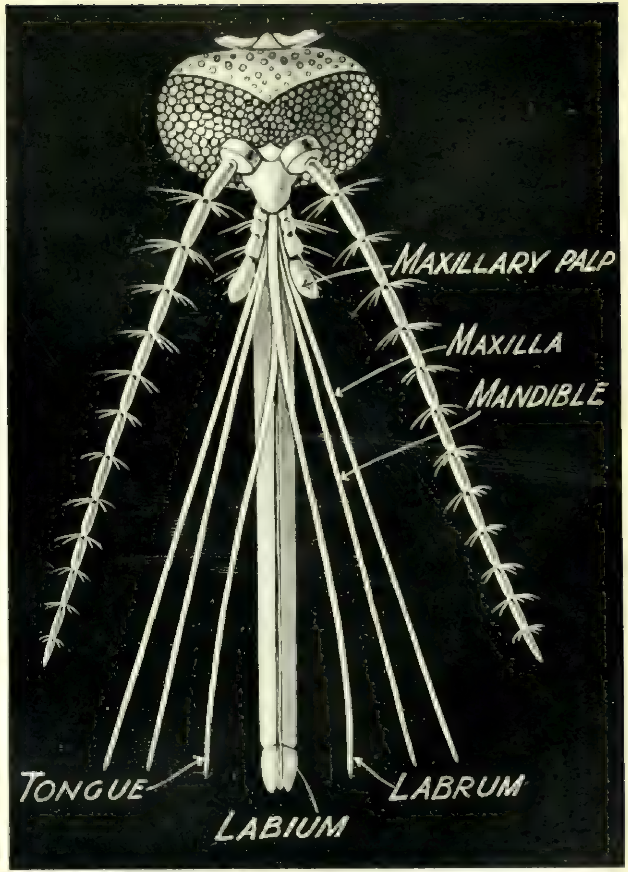
Still more remarkable are the mouth-parts of a gnat or mosquito. Not only are the mandibles and first

maxillæ elongated to form needle-like processes, but the tongue and the labrum (or upper lip) are similarly modified, and work in conjunction. All these six lancets, when not in use, lie within a grooved sheath formed by the labium. But when the tip of this sheath is applied to the skin of a victim, and the rapid plunging and cutting of the lancets begin, the sheath curves bow-like beneath the insect's head, while the rigid lancets escape from the groove and are thus free to be driven deeper into the tissues. The bifid tip of the labium, however, continues to surround the lancets, and slides along them as the skin is penetrated. The actual sucking-tube appears to be formed by the union of the modified upper lip and the tongue, the mandibles and maxillæ being chiefly used to enlarge the puncture and increase the flow of blood. Each salivary gland of the gnat is three-lobed, and the middle lobes secrete a poisonous fluid which runs down the tube formed by the tongue and the labrum. This poison probably retards coagulation of the blood and stimulates its flow, although originally it may have acted upon proteids in the juices of plants—the blood-sucking habits of gnats and their kindred being comparatively recent in origin.

In the common house-fly, or the bluebottle, all the mouth-parts except the labium are suppressed; but the latter is a complex organ, and expands at the tip into a bilobed, fleshy pad. Each lobe contains about thirty channels that act as tributaries to two central tubes, which, in their turn, lead to the mouth, and are in communication with the salivary ducts. The sixty channels are really so many inverted gutters. Each one is open to the air on the underside of the pad, while each is supported inwardly by a closely set series of incomplete rings, or arches, of chitin. The salivary glands of the fly are

PLATE IX

Head of Death's Head Moth (from beneath) showing mouth-parts



Head of Gnat (from above) showing mouth-parts (after Folsom)

very large, extending right down into the abdomen, and the flow of saliva is proportionately copious. Thus, when the fly wishes to feed—upon a lump of sugar let us say—it simply applies the tip of its labium to the substance, floods the sixty channels with saliva, and then sucks this back again together with the sugar which has been dissolved. Between these two extremes—the gnat and the house-fly—almost every conceivable adaptation of the mouth-parts for piercing and sucking may be found among two-winged flies; while in the case of the bot-flies the mouth-parts are practically obsolete, and the adult insect takes no food. Yet all these marvellous changes are believed to have been effected by twisting, lengthening, compressing, remodelling, or suppressing the three pairs of ancestral foot-jaws with which insects were originally endowed.

Next to the mouth-parts of an insect the wings are its most characteristic feature. Indeed, if we find out how a given insect eats, and what kind of wings it possesses, we can usually interpret its natural affinity. We have already seen that the typical insect has two pairs of wings, that these spring from the second and third segments of the thorax, and that they consist of a twofold layer of skin. Each wing is supported by longitudinal veins, or *nervures*, which are often connected by cross *nervules*, the number and arrangement of which are so constant in the same kind of insect that an expert can usually refer a detached wing to its correct genus, and often to its species.

In some insects, notably dragon-flies, the two pairs of wings are alike in size and form; but more commonly the fore-wings are both larger and broader than the hind-wings, as in the case of may-flies, bees, and wasps. Sometimes, however, the fore-wings are relatively narrow, more

or less firm in texture, and are used to cover and protect the hind-wings when the insect is at rest, as in cockroaches, grasshoppers, and crickets. Such thickened fore-wings are called *tegmina.* The horny fore-wings of beetles—a further development along the same lines—are termed wing-cases, or *elytra;* and while they appear to play a passive part in flight by acting as balancers, possibly also as gliders or kites, they can hardly be considered as wings at all.

Among the strange stick and leaf insects of the family *Phasmidæ* the fore-wings are usually very small or entirely wanting; while the hind-wings are often large and beautiful structures, which fold up like a fan beneath a firmer front portion of the wing. There is also a group of small parasitic insects called *Stylopidæ* whose males have the posterior wings well developed, the fore-wings being rudimentary. But in all true flies the hind-wings are suppressed, their place being taken by a pair of stalked knobs, called *halteres* or balancers, which are thought to be chiefly useful as sense-organs. A few flies, such as the sheep spider-fly, or "ked," often miscalled the sheep-tick, as well as fleas and most other parasitic insects, have no wings. There are, too, other wingless insects scattered throughout the orders; but most of them are closely related to kinds which have wings. Reference has already been made to species of moths in which the females are wingless, although the males have fully developed wings and are good fliers; also to the common cockroach, the sexes of which exhibit a similar phenomenon. The aphides, often wingless, produce winged broods at certain seasons of the year, or when a dwindling food-supply makes emigration to other plants desirable. Furthermore, certain insect communities, such as those of ants, comprise wingless "workers" and wing-bearing males and females.

On the whole, therefore, it seems probable that all existing insects descended from winged ancestors, with the possible exception of the silver-fishes and their allies. As none of the latter insects has even traces of wings, some authorities believe that they represent a primitive, wingless stock; but, in the opinion of Sir Ray Lankester, their independence of a winged ancestry has been attributed without sufficient reason.

The origin of insects' wings is still open to question. The suggestion has been made that they were derived from gills possessed by remote aquatic progenitors, and some colour is lent to this theory by the fact that the wings are traversed by air-tubes, with which blood spaces are always associated in early stages of development; while there is reason to think that, even in some adult insects, the blood circulates in the wings to some extent. Such an assumption, however, presupposes for insects an aquatic ancestry; and this is highly improbable. "The immense majority of insects" (writes Professor Carpenter) "are terrestrial or aerial, and the aquatic forms appear to have been modified from their land relations. Such evidence is admitted by zoologists as conclusively showing the native element of any class of animals; mammals are universally regarded as primarily terrestrial, though seals and whales are marine; crustaceans as aquatic, though some crabs and wood-lice live on land. It may be admitted readily that life began in the water, and that to the waters we must go for the remote progenitors of insects. But the class as we know it now is composed of typically land-animals, and we have every reason to believe that its immediate ancestors were air-breathers." These considerations lead us to the more plausible suggestion that the structures which have been gradually specialised into wings arose, in the first instance, as para-

chute-like outgrowths from the sides of the body. Such outgrowths would act as gliders, enabling the insect to prolong its leaps; and it is interesting to note that an Australian spider actually possesses folds or flaps, one on each side of the abdominal region, which spread out when the creature launches itself into the air. Analogous contrivances are seen in other animals, such as the Australian flying phalanger—the so-called "sugar squirrel," the flying squirrels of the Northern Hemisphere, a few lizards and at least one frog; while the flying-fish rushes at high speed through the water, hurls itself into the air, and spreading its huge, wing-like fins, glides rapidly forward until its momentum is exhausted. Professor J. R. Ainsworth Davis has pointed out that when once the ancestors of insects had developed parachute-folds, useful for gliding from one twig or grass-stem to another, "the establishment of joints between the folds and the thorax would be of service in guiding even parachute movements, and from this stage on it is not difficult to imagine the gradual modification of the folds into wings."

The manner in which insects fly has been investigated by Professor E. J. Marey, the chief authority on animal locomotion. Briefly, the wing may be regarded as a lever, the fulcrum of which is situated at a point where the base of the wing projects into the thoracic cavity. To the short arm of the lever a muscle is attached by which the wing is raised; while a stronger muscle, by means of which the powerful down-stroke is effected, is attached to the long arm just beyond the fulcrum—*i.e.* just outside the wing joint. Other muscles, which are not attached directly to the wing, assist flight by altering the shape of the thorax as the wings rise and fall; but by an elaborate series of experiments Professor Marey showed that, owing to the structure of the wing itself, simple up and down

movements are sufficient, at least for the simplest form of flight. The anterior margin of an insect's wing is strengthened by a more or less elaborate system of thickened nervures, and is thus kept rigid, while the membranous hind part yields readily to air pressure; so that during oscillation the plane of the wing constantly changes its inclination with respect to the axis of the insect's body. In the ascending stroke the upper surface of the wing inclines backward, while in the downward stroke the same surface inclines forward. This was demonstrated by gilding the tip of a wasp's wing, and allowing the insect to fly in the sunlight. A brilliant and continuous image of the wing in its successive positions was thus obtained; and its tip was seen to describe a very elongate figure 8. Now an inclined plane which strikes the air has a tendency to move in the direction of its own inclination; so that whether the wings of an insect are ascending or descending, forward action is still maintained. Professor Marey constructed a mechanical model of an insect's wing, and by moving this rapidly, in a vertical plane, between two lighted candles, showed that while the flame near to the thin edge of the wing was strongly blown away by the current produced, that near to the thick edge was equally strongly drawn inwards —thus showing that the current of air is in the same direction both in the upward and downward strokes of the wing. By the movement of an insect's wings, therefore, "an effect is produced analogous with that which takes place when an oar is used in the stern of a boat in the action of sculling. Each stroke of the oar, which presents an inclined plane to the resisting water, divides the resistance into two forces; one acts in a motion opposed to the motion of the oar, the other in a direction perpendicular to that movement, and it is the latter which

D

impels the boat." With equal aptness we may liken the movement to the screw-propeller of a ship or an aeroplane, for the screw may be considered as an inclined plane whose movement is continuous, and always in the same direction.

The frequency of wing-vibration may be roughly estimated from the musical note made by the insect as it flies—that is, if the wings vibrate rapidly enough to produce an audible sound; but it may be graphically determined, and with greater accuracy, by means of an instrument called the kymograph. This consists of a cylinder, covered with smoked paper, and revolved by clockwork at a uniform rate. The insect is held, in a delicate pair of forceps, in such a way that one of its wings brushes against the blackened paper at every movement. Each of these contacts scrapes off a small part of the sooty deposit, and exposes the white paper below; and, as the cylinder revolves, new points continually present themselves to the wing-tip. Professor Marey's kymograph revolved once in a second and a half; and by comparing the record made by the insect with one made by a tuning-fork of known vibration period, the frequency of the wing movement was determined with great accuracy. Some of his results were as follows:—

	Wing-beats per second.
Common fly	330
Drone-fly	240
Bee	190
Wasp	110
Humming-bird hawk-moth	72
Dragon-fly	28
Small white butterfly	9

Obviously, the movements of the captive insects must have been retarded by friction; but these figures clearly

show that the smaller the wings are in proportion to the body, the more rapidly they vibrate. Nor is this surprising. Without bulk of body, the muscular force necessary to secure a firm grasp upon the air, and to repeat at rapid intervals the effective downward thrust, cannot be developed. Thus, we see that as the weight of the insect increases, the relative wing-area usually decreases, a small wing moved rapidly being more effective than a large one moved slowly. The gnat, despite its comparatively feeble flight, has eleven times the wing surface of the swallow, reducing both animals to the same weight. Compare, too, the wings of the small white butterfly with those of the humming-bird hawk-moth, and these again with the wings of the bee or the fly. Further, there is a reason why weight may be regarded as an important asset in flight. We know that within certain limits imposed by our muscular strength, we can throw a large stone to a greater distance than a small one. We say that the former "carries" better than the latter. By this we mean that when once it is set in motion the momentum of a heavy body is far greater than that of a light one. It follows that the body of an insect must not be regarded simply as a dead weight to be upheld by the wings, but as an actual aid to rapid and sustained flight. Once set fairly swinging through the air by the movement of the wings, the body travels forward by its own momentum, just as does a stone when it leaves the hand of the thrower. Moreover, the bodies of rapidly-flying insects are perfectly adapted by their shape and poise to minimise the resistance of the air—to utilise, as it were, the last fraction of the force which the wings develop. If we contrast the swift, fully-controlled flight of a hawk-moth or a bee with the relatively feeble flutterings of a butterfly, we may say that the former is like a well-ballasted

ship, propelled by powerful machinery, and possessing ample "steering-way"; while the latter resembles a sailing ship "riding light" with all sails set, driven mercilessly before the prevailing wind.

Insects' bodies contain air-sacs, which are in communication with the tracheæ; and these are especially large in swift-flying forms, such as dragon-flies, moths, bees, and flies. Before flight, they are charged by a deliberate act of inspiration, the specific gravity of the insect being thereby slightly reduced. We have seen, however, that too much stress must not be laid upon mere lightness of body; and there can be little doubt that the air-sacs are chiefly important because they act as reservoirs, and assist respiration during the severe muscular exertion coincident to rapid flight.

While up and down movements of the wings suffice for the simplest kind of insect flight, the process becomes more elaborate as efficiency increases, and the muscles are proportionately more numerous and complicated. Thus, in the case of dragon-flies, the two pairs of wings are capable of independent action, although they can also be worked in unison; while in addition to the elevator and depressor muscles there are others by means of which the wings may be rotated and otherwise adjusted. In many four-winged insects, however, the two wings of each side are united when in use by a series of hooks, or some other simple mechanism, and strike the air as one. As the precise method of attachment has an important bearing on insect affinity, we shall refer to it again in the next chapter.

With respect to the way in which an insect regulates its flight, Professor Marey has the following passage: "We need only observe the flight of certain insects, the common fly, for instance, to see that the plane in which the wings

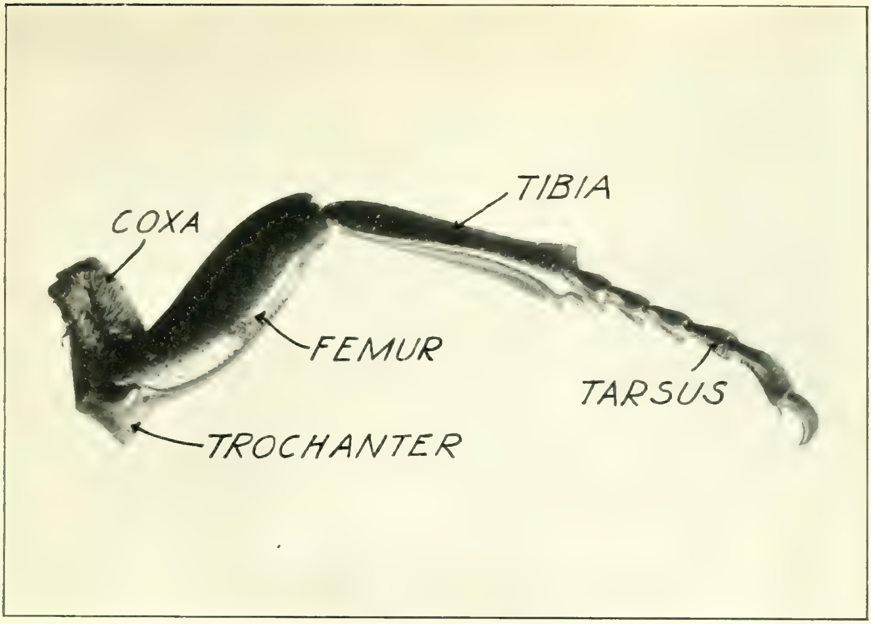
move is not vertical, but, on the contrary, very nearly horizontal. This plane directs its upper surface somewhat forward, and therefore the main-rib of the wing corresponds with this surface. Consequently, it is from below upwards and a little forward that the propulsion of the insect is effected. The greater part of the force exerted by the wing will be employed in supporting the insect against the action of its weight; the rest of this impulse will carry it forward. By changing the inclination of the plane of oscillation of its wings, which can be done by moving the abdomen so as to displace the centre of gravity, the insect can, according to its wishes, increase the rapidity of its forward flight, lessen the speed acquired, retrograde, or dart toward the side. It is easily to be seen that, when a Hymenopterous insect (*e.g.* a bee) flying at full speed stops upon a flower, this insect directs the plane of the oscillation of its wings backward with considerable force. Nothing is more variable, in fact, than the inclination of the plane in which the wings of different species of insects oscillate. The Diptera (two-winged flies) appear to have this plane of oscillation very nearly horizontal; in the Hymenoptera (bees, wasps, &c.), the wings move in a plane of nearly 45°, but the Lepidoptera (butterflies and moths) flap their wings almost vertically, after the manner of birds."

We have seen that insects' legs do not work in pairs, but in two sets of three. With the fore-leg a tractile effort is produced, the hind-leg pushes the body forward, and the mid-leg acts in the main as a support, though it also does some of the pushing work. Thus, we may say that while insects creep with their fore-legs, they walk with their hind-legs. Typically, each leg is made up of five principal parts. First there is the haunch, or *coxa*,

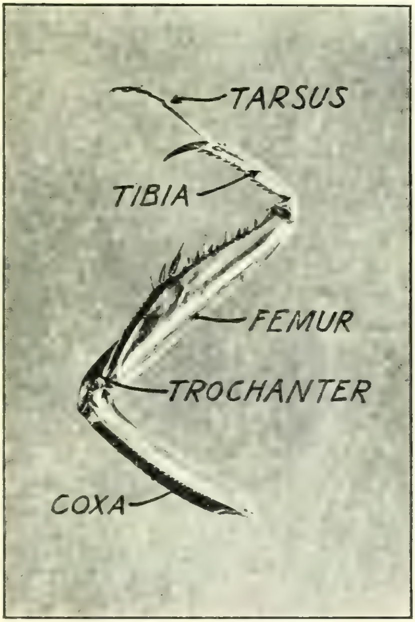
which fits into a socket in the thorax; second, a small joint called the *trochanter*, which in some cases is divided into two; third, the thigh or *femur;* fourth, the shin or *tibia;* fifth, the foot or *tarsus*, which normally consists of five joints, although the number is sometimes four or three, and in exceptional cases two or even one. The last joint is provided with a pair of *claws*.

The legs of insects have been subjected to the greatest modification in accordance with the special requirements of their owners. In the mole-crickets, the fore-legs are elaborate burrowing implements, the tibia and tarsus being so arranged that they act as shears for cutting roots. Some insects have become quadrupeds so far as walking is concerned owing to the specialisation of their fore-legs. In the so-called praying mantis, or rearhorse, the fore-legs constitute a kind of trap which is used for seizing prey; a somewhat similar contrivance is seen in the case of water-scorpions; while in many butterflies the fore-legs are greatly reduced in size and quite useless for walking. The middle legs are not usually greatly modified, but in some water-bugs they are the longest and strongest of all the legs, and are used as sweeps, by means of which the insect propels itself through the water. In most aquatic insects, however, the hind-legs are the chief means of propulsion. The hind-legs of grasshoppers and locusts, as well as certain beetles, are very long and powerful, enabling the insect to spring high into the air.

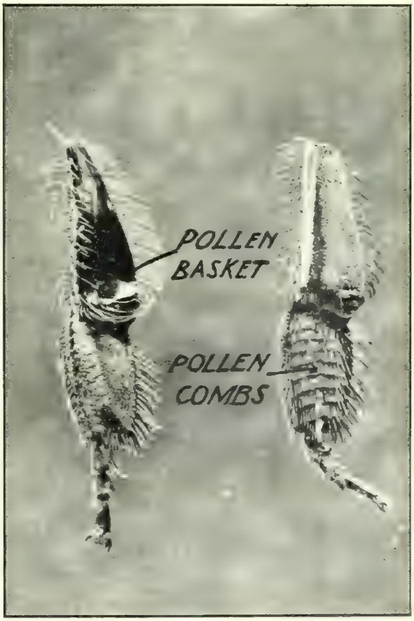
In many insects the legs serve certain minor purposes unconnected with locomotion. Thus, in many beetles a cavity in the front shin, lined with bristles, serves as a comb for cleaning the antennæ; while in the case of bees and wasps there is a still more elaborate contrivance for the same purpose near the upper end of the first tarsal segment. Again, the abortive fore-legs of many butter-



Leg of a Beetle



Fore-leg of a Mantid



Tibia and tarsus of hind-leg of Worker Hive-bee (*Apis mellifica*), outer (to left) and inner aspects: greatly magnified

flies are clothed with hairs, and are used as toilet brushes for removing dust from the insect's eyes and face. The Nymphaline butterflies, of which our peacocks and red-admirals are good examples, have for this reason been termed "brush-footed." The most wonderful contrivances, however, are found on the hind-legs of pollen-gathering bees, especially the hive-bee. In the latter insect, the proximal segment of the tarsus—*i.e.* that which is joined to the tibia or shin—is as long as all the rest put together, and very broad. It is called the *planta* or *metatarsus*. Its inner surface is beset with ten transverse rows of stout hairs or bristles, which are used for combing the pollen out of the insect's hairs. The tibia, on its outer face, has a longitudinal concavity—the *corbiculum* or pollen basket—which is fringed with recurved hairs; and in this the pollen is packed for transport. The broad, sharp edges at the juncture of the tibia and planta are used as nippers for holding and cutting wax. The foregoing remarks apply exclusively to the "worker" bee. The hind-legs of the queen, and of the drones or males, not being used for pollen-collecting, are destitute of baskets, pincers and combs, and are shaped differently.

Many insects which walk with their tarsal segments flat upon the ground have the under surface of these joints broadened to afford support; while there is often a cushion-like pad, called the *pulvillus*, between the bases of the claws. In flies, some bees, and many beetles, the pulvillus is an adhesive organ, being furnished with glandular hairs, which secrete a sticky substance, thus enabling the insect to obtain a foothold upon smooth surfaces, or to walk upside down. When the insect is walking over a rough surface, and the claws provide adequate foothold, the pad can be raised so as to escape

injury. The spinous legs of dragon-flies form a kind of basket for catching prey on the wing; they also enable the insect to cling to a leaf or a grass blade, but they are of little service for walking. Indeed, in most adult insects which pass the greater part of their lives in flight, the legs are relatively feeble; while a few simplified insects have no legs at all.

Three pairs of thoracic or "true" legs, each terminating in a single claw, are present in most larvæ—one pair on each of the three segments immediately succeeding the head; but caterpillars also possess a varying number of abdominal claspers or prolegs. Each proleg generally ends in a circlet of minute hooks, by means of which a firm hold is gained. The caterpillars of butterflies and moths usually have ten prolegs—a pair on the seventh, eighth, ninth, tenth, and thirteenth segments of the body (the head being reckoned as the first segment), but many "looper" caterpillars, of the family *Geometridæ*, have only two pairs—on the tenth and last segments respectively. When walking, they first bring the hind part of the body forward, so that the tenth segment almost touches the fourth; then, leaving the prolegs fixed, they stretch out the body to its full length, and take hold again with the three pairs of thoracic legs. Thus their progress consists of a series of loops, whence their popular name. The caterpillars of saw-flies have seven or eight pairs of prolegs, while those of scorpion-flies have eight pairs. Many other larvæ have abdominal organs which assist locomotion, but they are not so highly specialised as the prolegs of caterpillars.

CHAPTER V

THE CLASSIFICATION OF INSECTS

The Greek philosopher Aristotle (384–322 B.C.), justly called the "Father of Natural History," divided animals into two great groups, viz. those with red blood and a backbone, and those without. The latter, or Invertebrata, he subdivided into molluscs, scaly animals, animals with soft scales, and insects. The insects he yet further subdivided, and three of his groups—Coleoptera or beetles, Psychæ (Lepidoptera) or butterflies and moths, and Diptera or two-winged flies—hold good at the present day. But it is to the Swedish naturalist Karl von Linné, better known by the name of Linnæus (1707–1778), that we owe the method of classification which is now in use. He arranged all the plants and animals that were known to him in accordance with a definite system, calling the largest groups classes, and subdividing these into orders, genera and species. He also instituted the practice of giving each species a double name. For example, we have in England three kinds of large butterflies with silvery markings on the hind-wings beneath, their respective popular names being the "silver-washed," "dark green," and "high brown" fritillaries. According to the Linnæan principle, their double scientific names are *Argynnis paphia*, *Argynnis aglaia*, and *Argynnis adippe*. Moreover, there are other members of the same genus, not only in Britain but in many countries of the northern hemisphere: and in the event of a new species being

discovered, it would be given a specific name of its own, although its generic name would be waiting for it. Every insect, in fact, is accommodated by science with a first or generic and a second or specific name, just as every civilised man or woman has a surname and a Christian name. It will be noticed that the generic name is placed first. This is a mere matter of convenience, exactly as surnames are placed first in official documents, such as lists of voters.

The classification of Linnæus was little more than a system devised to facilitate the identification of species. Nevertheless, all the great naturalists, from Aristotle onward, perceived that living things are not merely a crowd of isolated species, but that certain affinities exist among them. In 1812, Cuvier actually likened the relationship to the branchings of a tree; but it was not until Darwin, in 1859, established his theory of descent, that the true significance of this comparison became apparent. It was then seen that the relations which the older naturalists had been trying to indicate in their schemes of classification were really the branches of a huge pedigree.

For this reason the orders of insects must not be regarded as so many rigidly defined groups, but rather as twigs diverging from a branch which, in its turn, has its origin in the main stem of animal life. Naturally, there are great gaps in our knowledge of insect lineage, many species having died out, leaving no trace behind them. Thus, men of science are not always agreed as to the precise relationship of one group to another. But it is believed that if all the "missing links" could be reinstated, the complete genealogy of insects could be established.

Many naturalists recognise seven orders of the class Hexapoda, or Insecta, namely:—

Orthoptera (or straight-winged).
Neuroptera (or nerve-winged).
Coleoptera (or sheath-winged).
Hymenoptera (or membrane-winged).
Lepidoptera (or scale-winged).
Diptera (or two-winged).
Hemiptera (or half-winged).

In the first three orders—Orthoptera, Neuroptera, and Coleoptera—all the mouth-parts are formed for biting; in Hymenoptera the mandibles, as such, are always present, but the other mouth-parts are usually adapted for licking and sucking; while in the three last orders—Hemiptera, Lepidoptera and Diptera—all the mouth-parts are definitely modified for sucking, or for piercing and sucking. This arrangement of insects, however, does not account for certain small groups of parasitic, or semi-parasitic forms, such as the fleas; while it includes in the order Neuroptera an assemblage of families which differ greatly in their life-histories, and in many details of their structure. We shall be well advised, therefore, to follow the more extended scheme of classification adopted by Professor Carpenter in the current edition of the *Encyclopædia Britannica,* in which nineteen orders are recognised.

Order I.—Aptera.

This order is made up of tiny insects, typically mandibulated, which never develop wings. They undergo no kind of metamorphosis, the newly-hatched young resembling the adults except in size. The segments of the body are more clearly defined and less modified than

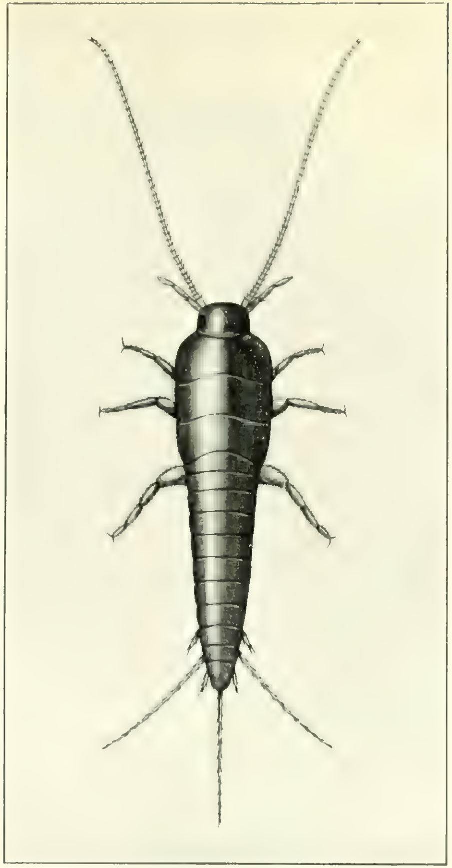
in any other insects, while "locomotor abdominal appendages" are often present in the adult. The order comprises two sub-orders, viz. :—

Sub-Order 1.—Thysanura.

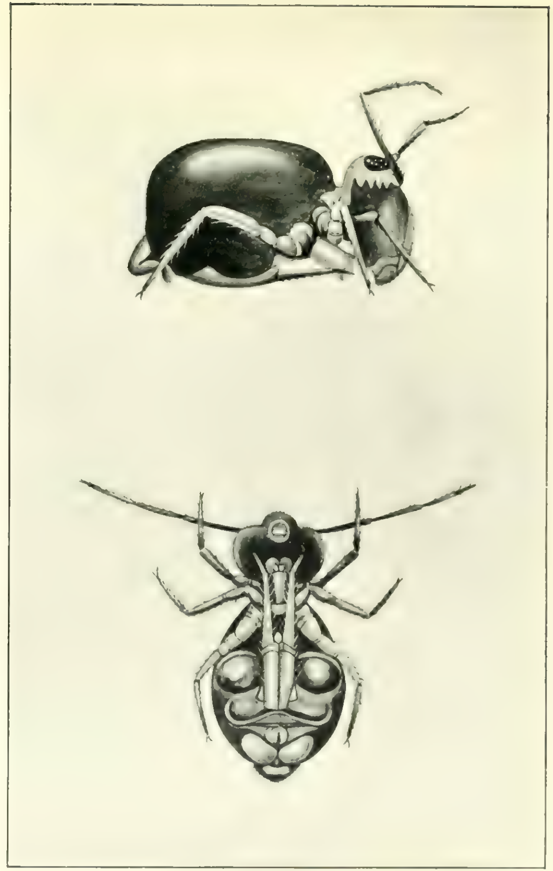
These are the lowliest of all living insects. They are known popularly as "bristle-tails," on account of the long styles, or cerci, which often project from the hinder end of the body; also as "fish insects," because many of them are clothed with shining scales very similar in appearance to those on the skin of fishes. One small, nearly white species, called *Campodea staphylinus*, is common in garden mould and under dead leaves. Better known, however, is *Lepisma saccharina*, the "silver-fish," or "silver-lady" of our cupboards and pantries. It feeds upon a great variety of substances, and sometimes does mischief to old prints, books, &c., by gnawing away the surface of the paper. An allied species is *Thermobia furnorum*, which frequents London warehouses and bakeries, where it is termed the "fire brat." Other species are found on the sea shore. In all Thysanura there are ten abdominal segments, some of which carry pairs of rudimentary "limbs."

Sub-Order 2.—Collembola.

These are the "spring-tails," so-called because many of the species have a curious leaping apparatus attached to the under surface of the abdomen. This is a kind of two-pronged fork by means of which the insect can hurl itself into the air. Spring-tails may be found among decaying vegetable matter, under bark, and on the surface of stagnant water. According to Mr. C. O. Waterhouse, "one small, white species (*Isotoma fimetaria*) can live equally well on land and on the top of water; and as it



The "Silver-fish" or "Silver-lady" (*Lepisma saccharina*): greatly enlarged (after Lubbock)



A Springtail (*Papirius*): greatly enlarged (after Lubbock).

can live under water for many weeks it has at times caused some trouble by getting into cisterns." At least one species (*Anurida maritimia*) frequents salt water, being found abundantly upon the surface of rock pools on the shores of the English Channel. Others are characteristic of Alpine regions, where they disport themselves on the surface of the snow or ice, and are known as "snow-fleas" or "snow-worms."

ORDER II.—Dermaptera.

This is the order of the earwigs. These insects were formerly placed with the Orthoptera, but owing to certain peculiarities of structure they are now usually treated as a distinct group. The fore-wings are represented by oblong plates, which serve as covers for the hind-wings. The latter are unique structures, consisting of a firm basal piece, whence radiate numerous nervures which support a delicate membrane. By a fan-like radial closing, and two transverse folds, each hind-wing can be packed away beneath the corresponding fore-wing, or elytron. Another characteristic feature is the pair of forceps at the end of the abdomen. These vary very much in shape in different species, while they are usually larger and more complex in the male than in the female. Some species, at least, employ their forceps in the process of packing up their wings. Earwigs have biting mouth-parts, and feed chiefly upon vegetable substances; but they also attack and devour other insects. Their metamorphosis is incomplete, the young resembling their parents except in size and the absence of wings. They are most abundant in the tropics, but they are represented in all parts of the world. The common British earwig is *Forficula auricularia*, while a much

smaller species, known as *Labia minor*, is also abundant. The order Dermaptera includes the small family *Hemimeridæ.* These remarkable insects are blind and wingless. They inhabit West Africa, and one species is known to live among the hairs of a rat or "ground pig," and other small mammals, and is believed to prey upon the parasites of its hosts.

ORDER III.—Orthoptera.

This order includes the cockroaches, mantids, "stick" and "leaf" insects, locusts, grasshoppers, and crickets. They agree in possessing biting mouth-parts, while the second maxillæ are not so closely fused together as in most other insects. Their metamorphosis is always incomplete. When present the fore-wings are modified into leather wing-cases, or tegmina, which close over and protect the delicate, fan-like hind-wings when the insect is at rest. Many species, however, are wingless. Orthoptera fall naturally into two groups. In the first, which comprises the cockroaches, mantids, and stick insects, the hind-legs are formed for running or walking.

The cockroaches (*Blattidæ*) are especially characteristic of tropical countries. There are only three indigenous or "wild" British species. These live among moss, dead leaves, and low-growing herbage; and in the summer they may sometimes be seen in numbers flying from one leaf or stem to another, or basking in the sun's rays. Several species of cockroaches, however, frequent houses and ships, and have become almost cosmopolitan in their range. Of these the best known are the German cockroach (*Phyllodromia germanica*), the American cockroach (*Periplaneta americana*), and *Blatta orientalis*—which is the common "black beetle" of our kitchens. This insect

is said to have been brought to Europe from the East about two hundred years ago, but its place of origin is not definitely known. Cockroaches are omnivorous feeders. Many species are more active at night than in the day-time. Their eggs are laid in curious purse-like capsules.

The mantids, or "praying" insects (*Mantidæ*), are easily recognised by their powerful front legs, which are not used for walking, but are held up in an attitude suggestive of devotion—hence the popular name. If a fly, or some other insect, comes within reach, these legs are shot out with great rapidity to effect its capture, and are subsequently used to hold the prey while it is being devoured. The effective, trap-like part of the fore-leg consists of the femur and tibia, the tarsus being small and apparently almost functionless. The first ring of the thorax (prothorax) is greatly lengthened. Mantids are numerous in all tropical countries, but only a dozen species represent the family in Southern Europe, one only (*Mantis religiosa*) being found at any great distance from the Mediterranean littoral. They lay their eggs in curious capsules formed from a glutinous secretion that hardens after exposure to the air. These capsules vary in form and appearance, and are always attached to some object, such as a twig or a grass stem.

In the remarkable "stick" and "leaf" insects (*Phasmidæ*), the middle ring of the thorax (mesothorax) is the longest segment of the fore-body. When fore-wings are present they are usually reduced to mere scales, the delicate membranous area of the hind-wing folding fan-wise beneath a firmer front portion. But among the "leaf" insects (*Phyllium*), the tegmina of the females are large and leaf-like, the hind-wings being obsolete. These insects, moreover, have a flattened form, whereas in most Phasmids the bodies and legs are very long and slender.

Many of the species are wingless throughout life, while some possess the unusual power of reproducing a lost limb. Phasmids are vegetable feeders, and although sluggish in their habits are very voracious. In Fiji and the Friendly Islands, a species called *Lopaphus cocophagus* injures the cocoa-nut palms by eating the foliage, and, according to Dr. Sharp, "one writer has gone so far as to attribute the occurrence of cannibal habits amongst the inhabitants of some of these islands to the want of food caused by the ravages of this insect." Like mantids, phasmids are for the most part tropical in their distribution. There are four or five European species, only one of which ranges as far northward as Central France.

The second group of Orthoptera is characterised by the great length and power of the hind-legs, which are formed for leaping. Its members are also remarkable for possessing very perfect auditory structures, or "ears"; while the males can usually produce chirping sounds.

The locusts and grasshoppers (*Locustidæ*) are distinguished from other leaping Orthoptera by their relatively short antennæ and three-jointed tarsi. An "ear" is found on each side of the abdomen at its base, while a chirping sound is produced by scraping a file-like ridge which exists on the inner side of the femur of the hind-leg against a prominent vein on the wing. So far as is known, however, only the small species—the "grasshoppers"—possess this musical apparatus. All the *Locustidæ* are vegetable feeders, and some of them (the true locusts) migrate in enormous swarms and work serious injury to crops in warm countries. The family is represented in all parts of the world, a number of small species being indigenous to Britain.

The long-horned or tree grasshoppers (*Phasgonuridæ*) may be distinguished from the *Locustidæ* by their very

long, thread-like antennæ and four-jointed tarsi. An "ear" is often present at the base of each front tibia, or shin; while the males of many species "chirp" by rubbing a file-like ridge, situated on the underside of one wing, over a sharp ridge on the upper surface of the wing beneath. In a few genera both sexes are provided with sound-producing structures. Tree grasshoppers feed upon leaves, but many species also attack caterpillars and other insects. The family is most numerously represented in the tropics, but several species—notably the large green grasshopper (*Locusta viridissima*)—are found in Britain.

The crickets (*Gryllidæ*) resemble the tree grasshoppers in many respects, their "ears" and chirping organs being similarly placed; but they have not more than three tarsal segments. They are represented in all parts of the world, four species being found in Britain. Of these, the wood cricket (*Nemobius sylvestris*) is apparently confined to the neighbourhood of the New Forest; while the field cricket (*Gryllus campestris*) and the mole cricket (*Gryllotalpa vulgaris*) occur only in a few isolated localities. But the house cricket (*Gryllus domesticus*) is probably the most familiar of all domestic insects. Its ancestral home is said to be North Africa—hence, probably, its well-known preference for the hearth and the oven. Most crickets live in subterranean burrows, while the majority are vegetable feeders, though the mole cricket is largely carnivorous.

Order IV.—Plecoptera.

This order includes the single family of the stone-flies (*Perlidæ*) which was formerly grouped with the Neuroptera. The mouth-parts are formed for biting, while the wings of both pairs are similar in texture, with a complicated net-veining. In the male, however, the

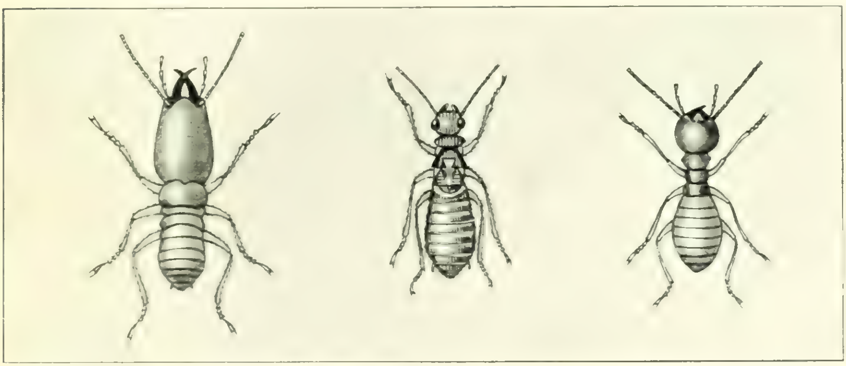
wings are often much reduced and useless for flight. The antennæ are long, while the last segment of the abdomen usually carries a pair of jointed cerci. Metamorphosis is incomplete, and the nymphal stages are passed under water. When full-grown, the nymph crawls out of the water, the skin splits down the back, and the winged adult emerges. Stone-flies, which are dull-coloured insects, have a world-wide distribution. About twenty-four species occur in Britain, the best known being *Perla bicaudata*, which is used by anglers as a good bait for trout.

Order V.—Isoptera.

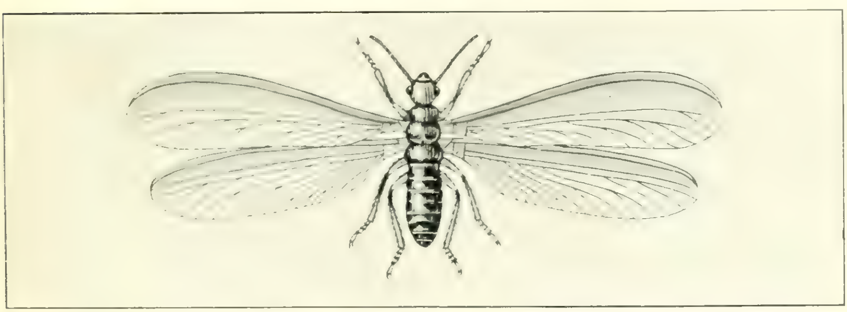
The "white ants," which make up this order, are more correctly called termites, since they are in no way connected with ants proper. They have biting mouth-parts, while the wings, when present, are all similar in form and texture, and have a transverse suture, or line of weakness, at the base. Most kinds of termites dwell together in social communities which comprise "kings" and "queens" —*i.e.* males and females—and a vast company of wingless forms, which are known as "soldiers" and "workers." Metamorphosis is always incomplete. The Isoptera are confined to the tropical and warmer regions. Two families are recognised: the *Termitidæ*, to which the foregoing remarks chiefly refer, and the *Embiidæ*. The members of the latter family are very peculiar insects, about whose habits very little is known, except that they have no workers or soldiers. The first segment of the front tarsus is provided with a gland, the secretion of which solidifies into a silken thread, and is used to form tunnels and galleries in which the insects live.

PLATE XII

Royal chamber (part of roof removed) and queen of West African Warrior Termite (*Termes bellicosus*)



Soldier, Female (after shedding wings) and Worker of a species of Termite (reading from left to right)



Winged Male of a species of Termite

The figures on this plate are adapted from specimens and drawings exhibited in the British Museum (Natural History)

Order VI.—Corrodentia.

This order comprises a number of small insects which have biting mouth-parts and undergo incomplete metamorphosis. They were formerly included with the Neuroptera. Two sub-orders are recognised, viz. :—

Sub-Order 1.—Copeognatha.

These are small, soft-bodied insects called *Psocidæ*—the only family of the sub-order. Wings are usually present in the adults, the fore-wings being much larger than the hind. Certain species, however, never develop wings, and among these are the familiar "book-lice." One kind, known as *Atropos divinatoria*, is often numerous in houses, especially if they are damp. It will attack and devour almost any kind of edible substance, including books and papers, while it is sometimes very destructive to collections of dried plants and insects. Many of the winged species are also very common, and may be found upon the trunks and branches of trees, where they feed upon lichens and fungi. They are represented in all parts of the world.

Sub-Order 2.—Mallophaga.

These are the small, large-headed insects which are commonly called "bird-lice" or "biting-lice." They are wingless, entirely parasitic, and spend their lives among the plumage of birds or the fur of animals. They feed, however, upon the delicate parts of the feathers and hairs, as well as on the dried secretions of the skin, and must not be confused with members of the order Anoplura (p. 74). Most of the species are associated with birds, though a few are found on mammals.

Order VII.—Ephemeroptera.

This order includes the may-flies (*Ephemeridæ*). In the adults the mouth-parts are very imperfectly developed, or quite absent; the hind-wings are much smaller than those of the front pair; while the antennæ are extremely short and bristle-like. Two or three very long tails, or cerci, are carried at the end of the abdomen. In their early stages, the may-flies are aquatic. Metamorphosis is incomplete, but the nymphs do not resemble their parents, being campodeiform, and perfectly adapted for an aquatic existence. Their mouth-parts are mandibulate, and they feed upon vegetable substances and small animals. May-flies are found in all parts of the world, upwards of three hundred species having been described. The common British may-fly—the "grey drake" of the angling fraternity—is *Ephemera vulgata*.

Order VIII.—Odonata.

The dragon-flies, which are comprised in this order, may be easily recognised by several well-marked characters. The head is large, and can be moved freely, owing to its slender attachment to the thorax. The antennæ are so small as to be scarcely noticeable, but the compound eyes are very large, while there are three simple eyes, or ocelli, on the brow. The mouth-parts are formed for biting, the mandibles being exceptionally large and powerful, while both pairs of maxillæ are flattened, and otherwise modified, so as to form—in conjunction with the hinged upper lip or labrum—a kind of trap for catching and holding the insects upon which dragon-flies feed. The thorax of the dragon-fly is very remarkable. When viewed from the side, its rings, or

segments, are seen to slope forward in such a manner that the coxæ of the legs are brought close together under the insect's head, while the bases of the wings are carried backward. By this means, all of the legs are thrust forward beneath the mouth, where they serve as a kind of basket for catching and holding prey. All dragon-flies possess four wings, which are approximately equal in size and form. The membrane of the wing is glassy in texture, and is traversed by a complex network of veins. Dragon-flies are also remarkable for the great length of the abdomen, which is relatively longer than in any other insect. The nymphs are entirely aquatic, and feed upon insects, snails, or indeed any creature with which they are strong enough to grapple. For the capture of their prey, they are provided with a unique development of the second maxillæ, or labium, called the "mask." This structure, when not in use, lies folded beneath the head; but it is jointed, and can be shot out with great rapidity, the prey being seized by means of terminal hooks and drawn back to the mouth. Although the nymphs differ markedly in appearance from the adult, metamorphosis is incomplete, for there is no motionless pupa state. The full-fed nymph climbs up the stem of a water plant, its skin splits dorsally, and the winged insect appears. Dragon-flies are represented in all parts of the world, except the far northern regions. Over forty species are found in Britain.

ORDER IX.—Thysanoptera.

These insects are known popularly as thrips. They are very small, and usually frequent flowers. The mandibles and first maxillæ are modified as piercers, and when in conjunction serve for sucking the juices of plants.

When present, the wings are exceedingly narrow, fringed with long hairs on one or both margins; but many species are wingless. The newly hatched young resemble the adults, save for the absence of wings; but prior to the last moult the nymph is sluggish, while in some cases it actually becomes quiescent, and takes no food. Thrips are probably world-wide in their distribution, but they have scarcely been studied outside Europe and North America. Perhaps the most common British species are the pea and bean thrips (*Thrips pisivora*) and the corn thrips (*Thrips cerealium*).

Order X.—Hemipteria.

This large order includes the very numerous insects which are known familiarly as "bugs," as well as cicadas, aphides, and their allies. In all cases the mandibles and first maxillæ are needle-like piercing organs, while in conjunction the mouth-parts form a suctorial apparatus. The head is usually triangular in shape, while the antennæ have from three to eight segments. There are two sub-orders, viz.:—

Sub-Order 1.—Heteroptera.

These are the true bugs, in which the basal portion of the fore-wing is leathery, although there is a transparent area towards the apex, or tip. The hind-wings are entirely membranous, and are folded on the back, beneath the fore-wings, when the insect is at rest. A shield-like plate, called the scutellum, is a prominent feature. It is the dorsal part of the second thoracic ring (mesonotum), and lies between the bases of the wings. The young closely resemble their parents, save for the absence of wings. This sub-order includes upwards of 10,000 known

species, their distribution being world-wide. Many families are recognised. Most of the species subsist upon the juices of plants; but some prey upon smaller insects, while a few suck the blood of birds and mammals. Many species pass the whole of their lives in water.

Sub-Order 2.—Homoptera.

In this sub-order the fore-wings are sometimes firmer than the hind-wings, but there is never a hard basal area. Commonly, the wings of both pairs are uniformly membranous, the hind-wings being relatively small; but there are many wingless species. The life-histories of these insects indicate they are on a higher plane than their congeners the Heteroptera. The newly-hatched young often differ from their parents in a marked degree, and may be regarded as true larvæ; while among scale insects there is a passive pupa-like stage before the last moult. All Homopterous insects suck the juices of plants.

The cicadas (*Cicadidæ*) have large wings of uniform texture. The males possess two drum-like membranes on the underside of the thorax, the vibration of which gives rise to a shrill sound, known as the "song of the cicada." The nymphs burrow in the ground, and suck the roots of plants. Cicadas abound in the tropics of both hemispheres, but are far less numerous in temperate regions. One small species is occasionally found in Britain.

The lantern-flies (*Fulgoridæ*) get their popular name from curious processes which project from the heads of certain species. These were formerly believed to be luminous; but this is not the case. The antennæ are placed beneath the eyes. The fore-wings are firmer in texture than the hind-wings; while in many species all

the wings are brilliantly coloured. An exotic sub-family includes the genus *Flata*, to which reference is made in a succeeding chapter. Many of the *Fulgoridæ* secrete large quantities of a white waxy substance from their abdomens. According to Dr. Sharp this wax forms a favourite food of certain caterpillars, and two or three kinds of maggots may frequently be found concealed in the wax of the living insect. The wax is also used by mankind, notably in China, for candles and other purposes. The *Fulgoridæ* are represented in all parts of the world, about seventy small species being found in Britain.

The frog-hoppers (*Cercopidæ*) are technically distinguished from the *Fulgoridæ* by having the antennæ between, not beneath, the eyes. As their popular name implies, the perfect insects have remarkable leaping powers. Most of them are small, but they often injure plants by puncturing the leaves and sucking the juices. The nymphs also live on plants, and commonly surround themselves with a frothy secretion. In its young state, the commonest British species, *Philænus spumarius*, is well known as the "cuckoo-spit" insect. There is another family of frog-hoppers known as the *Iassidæ*.

The allied family *Membracidæ*, for which no popular name appears to exist, has only two British representatives; but in tropical countries the species are very numerous. These insects are of small size, but many of them are very remarkable in form. The pronotum—*i.e.* the dorsal plate of the first thoracic ring—is produced behind into a long process, which varies greatly in shape, and often completely covers the whole of the insect's body. Sometimes this process acts as a kind of mask which suggests an insect of another order, or some object such as a seed or a thorn.

The plant-lice (*Aphidæ*) are only too well known to

PLATE XIII

Aphides or "Plant-lice" on a Rosebud (greatly magnified)

"Cuckoo-spit": caused by *Philaenus spumarius*

gardeners and agriculturists as "blight" or "green-fly." Many species carry a pair of abdominal tubes which secrete a waxy substance that first appears as oil-like globules. It was at one time supposed that the sweet liquid, called "honey-dew," was produced by these tubes; but it is now known that this is derived from the alimentary canal. Typical aphides have two pairs of delicate wings, with very few nervures; but in the case of most species wingless individuals are numerous. In the allied family *Psyllidæ*, which comprises the so-called "jumpers," or "springing plant-lice," the fore-wings are usually firmer in texture than the hind-wings. A well-known species is the apple sucker (*Psylla mali*) which often does much mischief in orchards.

The scale insects and "mealy bugs" (*Coccidæ*) are usually minute, but many of them are excessively injurious to cultivated plants. They are characterised by a great dissimilarity of the sexes, the adult males having long antennæ and a pair of well-developed wings, while the females are sluggish, grub-like creatures. Many species secrete shell-like scales; others, such as the felted beech coccus (*Cryptococcus fagi*), a waxy substance beneath which the insects live gregariously. Perhaps the best known member of this family is the mussel scale, or bark louse (*Mytilaspis pomorum*), which is found in all parts of the world where the apple is cultivated. The brown scale (*Lecanium*) and the cottony cushion scale (*Pluvinaria*) are also well known, both species being found on the twigs of currant bushes. Mealy bugs constitute the genus *Dactylopius*, while *Coccus cacti*, a native of Mexico and Central America, is the cochineal insect of commerce.

Order XI.—Anoplura.

Little need be said of these insects. By many authorities they are regarded as Heteroptera, which have become simplified as a result of their parasitic habits. They are all small and wingless, while the mouth-parts are modified to form a fleshy suctorial beak, which is provided with a circle of hooklets near the base. They spend their whole lives upon the bodies of mammals, whose blood they suck. Only one family is recognised, viz. the *Pediculidæ*.

Order XII.—Neuroptera.

In its restricted form, the order Neuroptera includes the alder-flies, ant-lions, lace-wings and their allies. All these insects possess biting mouth-parts, and (with few exceptions) four nearly similar wings with a complex net veining. They undergo a complete metamorphosis, a quiescent pupa state always preceding the appearance of the imago. Most of the species prey upon other insects. Their larvæ are of the campodeiform type. Their mandibles are usually grooved on the inner edges, and through these grooves the juices of the prey are drawn into the gullet. Thus, while the larvæ are typically mandibulate insects, they may nevertheless be said to feed by suction. The order Neuroptera comprises nine families.

Alder-flies (*Sialidæ*) lay their eggs in rows on grass stems, usually on the banks of rivers or streams. When the larvæ hatch, they enter the water, where they prey upon small aquatic creatures. When full-grown, they leave the water, and burrow in the earth, where they change to pupæ. There are several British species—the common alder-fly, which figures on the angler's list, being *Sialis lutaria*. The genus *Corydalis*, which is represented

in Northern India and the American continent, includes species which are remarkable for their gigantic size and the enormously developed mandibles of the males.

The snake-flies (*Raphidiidæ*) are relatively small insects, easily recognised by the snake-like appearance of the head and thorax, whence the popular name. The larvæ are very active, and live in rotten wood, or under loose bark, where they feed upon small insects. Snake-flies are confined to the northern regions of the Old World and to North America. There are three or four British species.

The ant-lion flies (*Myrmeleonidæ*) are especially interesting on account of the habits of their larvæ, some of which form conical pits and thus entrap their prey. Others lurk in crevices, or hunt in the open. A spherical cocoon is formed by the larva before it assumes the pupal state. The adult insects have a superficial resemblance to dragon-flies, but they have relatively long, clubbed antennæ. They are represented in most tropical and temperate regions, ranging into southern Sweden, but no species is found in Britain. The *Ascalaphidæ* are closely allied to the preceding family, which they resemble in their structure and metamorphosis; but their clubbed antennæ are much longer. In Europe, the family is represented only in the Mediterranean region.

The *Nemopteridæ* are distinguished by their long, narrow hind-wings, while their antennæ are not clubbed at the tip. The larvæ are of the ant-lion type, but possess elongated necks, not unlike those of snake-flies, and are very remarkable in appearance. This family is represented in Western and Central Asia, in South America, as well as in the Mediterranean region and Northern Africa. Another little family, the *Mantispidæ*,

must be mentioned because its members have a superficial likeness to the mantids of the order Orthoptera, due chiefly to the long prothorax and the manner in which the raptorial fore-legs are held. *Mantispidæ* may be distinguished from *Mantidæ*, however, by the fact that all their wings are similar in form and texture, and that the abdomen carries no cerci. According to Professor Carpenter, "the active campodeiform larva . . . makes its way into the egg-cocoon of a hunting-spider or the nest of a wasp, where it devours the developing spiders or grubs, becoming changed into a fat eruciform larva with stumpy legs. When full-grown, it spins a cocoon and pupates within the dried larval skin, so that the mantispid, on emergence, has to break through its own puparium and cocoon, as well as through the spider's egg-bag or the wasp's nest." These insects are very numerous in tropical countries, and one is found in Southern Europe, but there is no British representative.

A large number of closely related Neuropterous insects are known popularly as lace-wing flies. The larvæ frequent plants and prey upon aphides, from whose bodies they suck the juices. Some of the species cover their bodies with the dried skins of their victims. In one genus (*Osmylus*) the larvæ have exceedingly long mandibles, and are found under stones or among moss, often near or actually in water. The adult insects have been divided into two families, namely the *Chrysopidæ*, in which the antennæ are long, with cylindrical segments; and the *Hemerobiidæ*, in which the antennæ are relatively shorter, with bead-like segments. To the *Chrysopidæ* the name "golden-eye flies" is often applied, owing to the peculiar metallic lustre of the eyes in the living insect. Their eggs are very remarkable objects, each one being supported upon an immensely long stalk.

Both families are found in all parts of the world, and there are a number of British species.

The *Coniopterygidæ* are very small insects which secrete a white, powdery substance that covers the body. They are distinguished from other Neuroptera by their short wings, which have very few transverse nervules, and by the very small size of the hind pair. Some of their larvæ are known to feed upon scale insects.

Order XIII.—Coleoptera.

This, by far the largest order of insects, comprises the beetles, most of which may at once be recognised by their hardened fore-wings, or elytra, beneath which the hind-wings are folded when they are not in use. The hind-wings are occasionally reduced or absent (in the latter case the elytra may be fused together along their middle edges, forming a kind of shield above the abdomen); more commonly, however, they are well developed. The dorsal plate (pronotum) of the first thoracic ring is very large in all beetles; while the corresponding plate of the middle thoracic segment (mesonotum) is often visible as a triangular piece, called the scutellum, between the bases of the elytra. The legs vary greatly in accordance with the insect's manner of life, but the coxæ of the hind pair are usually large and powerful. The mouth-parts are formed for biting, and in some respects are reminiscent of the order Orthoptera; the second maxillæ, however, are very intimately fused together to form the lower lip or labium. In their development, beetles pass through a complete metamorphosis. The larvæ are very variable in form, and are active (campodeiform), or more or less sluggish and grub-like (eruciform), according to their manner of life. Generally speaking, the larvæ of a given family

are characteristic in form. The pupa is free. Beetles are found in all parts of the world, and enormous numbers of species have been described. These are grouped in many families, only a few of which can be mentioned here.

The tiger-beetles (*Cicindelidæ*) are represented in all parts of the world, though they are most abundant in the tropics. They are active, predaceous insects, with relatively large heads and long legs. There are several British species, the best known being *Cicindela campestris*. The larvæ, which have enormous grooved mandibles, make vertical burrows in the ground, where they lie in wait for their prey. The ground-beetles (*Carabidæ*) are nearly allied to the tiger-beetles, from which they may generally be distinguished by their heavier build and less prominent eyes. The larvæ live for the most part under stones and rubbish, or in the soil, and are inveterate insect hunters; but a few species are injurious to plants.

The carnivorous water-beetles (*Dytiscidæ*) are closely allied to the foregoing families, but they are adapted to an aquatic life, although they are able to fly well. Both they and their larvæ are very fierce and voracious. The whirligig beetles (*Gyrinidæ*) are an allied family. They propel themselves over the surface of ponds and rivers by means of their paddle-shaped legs; but their larvæ live entirely under the water. The *Hydrophilidæ* are also water-loving insects, distinguished by the great length of their maxillary palpi, which are often longer than the antennæ. Some of the species are completely aquatic, others frequent marshes. The best known British species is the large black water-beetle *Hydrophilus piceus*.

The rove-beetles, or "cock-tails" (*Staphylinidæ*), have short elytra not unlike those of an earwig, beneath which the hind-wings are packed when they are not in use. The most familiar example is the "devil's coach-horse"

(*Ocypus olens*); but there are more than 500 British species, most of them very small. The latter fly freely, especially in sunlight, and often cause annoyance by getting into the eyes of pedestrians and cyclists. Rove-beetles and their active, campodeiform larvæ feed for the most part upon small insects, molluscs, and worms, but some species subsist upon carrion, while others eat vegetable substances.

The family *Silphidæ* includes the well-known sexton beetles (*Necrophorus*); also the so-called "roving carrion beetles" of the genus *Silpha*. The latter are flat-looking insects, most of which feed upon decaying animal matter, though one or two species are known to eat the leaves of plants. The family also comprises many other forms, and includes most of the cave-dwelling beetles of Europe and North America. The smaller species live in moss, fungi, or under the bark of trees. The larvæ are sometimes very remarkable objects, those of the genus *Silpha* having the appearance of wood-lice.

The family *Trichopterygidæ*, to which reference has already been made, comprises a large number of minute species which are found among moss and dead leaves. The ladybirds (*Coccinellidæ*) are represented in all parts of the world, the two-spot ladybird *Coccinella bipunctata* and the seven-spot ladybird *C. septempunctata* being well-known British species. These insects and their larvæ feed upon aphides and scale insects, and are thus serviceable to mankind.

The family *Dermestidæ* includes a number of species which do great damage to food materials and other stored goods, the bacon beetle (*Dermestes lardarius*) being a well-known example. Others, such as the raspberry beetle (*Byturus tomentosus*), are injurious to plants.

The stag-beetles (*Lucanidæ*) are remarkable for the

great development of the head and mandibles in the males. The antennæ are elbowed, and end in a pectinated club. There are three British species, the best known being the common stag-beetle (*Lucanus cervus*). The sickle-shaped larvæ are white, fleshy grubs, with hard heads, powerful jaws, and feeble legs. They feed in wood, and take several years to reach maturity.

The family *Scarabæidæ* includes several well-marked groups, or sub-families, the most interesting being the scarabs or dung-beetles, the chafers, and the rose-beetles. It comprises the most gigantic of all beetles, the Goliath beetles of Africa, and the Hercules beetle (*Dynastes hercules*) of South America. All these insects are allied to the stag-beetles, and have antennæ which end in clubs formed of flattened comb-like plates. Their larvæ also resemble those of the preceding family.

The *Buprestidæ* are abundant in tropical countries, especially in Australia and Madagascar, but we have only a few small species in Britain. Many of the exotic forms are remarkable for the extraordinary brilliance of their colouring. Most of the larvæ are long, flattened grubs which feed under bark or in wood.

The "click beetles" (*Elateridæ*) are remarkable for the manner in which, when placed on their backs, they are able to leap high into the air. Their larvæ are the familiar "wireworms." The family is represented in all parts of the world. Some of the large tropical species emit light from paired spots on each side of the thorax, and are the "fire-flies" of the countries which they inhabit.

The family *Lampyridæ* includes the familiar "soldier-and-sailor" beetles (*Telephorus*), the glow-worms *Lampyris*), and the well-known fire-flies (*Luciola*) of Southern Europe. The larvæ vary greatly in form, many having a most bizarre appearance. Most of them are carnivorous,

some being known to feed upon slugs, snails, and worms. The adult beetles, however, usually frequent flowers. Many members of this family are luminous; while the female is often wingless and very like a larva in appearance, although the male conforms to the familiar beetle type. Certain South American species are said to emit a strong red light from the two extremities, and a green light from numerous points along the sides of the body. In Paraguay they are appropriately termed "railway beetles."

The family *Ptinidæ* comprises a large number of small oblong or oval beetles, many of which are extremely destructive. The larvæ are white, fleshy grubs, somewhat sickle-shaped like those of the stag-beetle and cockchafer. Both they and the perfect insects feed upon waste substances, dry timber and woodwork, and stored goods. *Anobium striatum* is the well-known furniture beetle or "death watch." An allied species (*A. paniceum*) feeds upon stored goods of many kinds, including capsicum and ginger, and is often the cause of much loss. This family is widely distributed, some of the species having been carried to all parts of the world together with the substances which they attack.

The long-horn beetles (*Cerambycidæ*) are characterised by the great length of their antennæ. They are represented in all parts of the world where trees can grow, and are especially numerous in the heavily timbered regions of the tropics. The family includes many thousands of known species, some of which are of great size. The larvæ are fleshy grubs, with hard heads, the body being more or less cylindrical, but not curved. They live and feed in the wood of trees, usually forming long burrows. Occasionally, however, a gall is produced, as in the case of our poplar long-horn beetle (*Saperda populnea*).

The *Bruchidæ*, represented by our bean and pea beetles (*Bruchus rufimanus* and *B. pisi*), make up a small family whose larvæ feed in seeds, chiefly those of leguminous plants. The female beetle lays her egg on the flower or the seed vessel, and the newly-hatched larva burrows through the pod and enters a developing seed, where it completes its metamorphosis.

The leaf-beetles (*Chrysomelidæ*) are closely allied to the long-horns, but they have shorter antennæ; while their oval, convex form, though unimportant from a scientific standpoint, is often a useful popular distinction. Many of the species are brightly coloured and brilliantly metallic. The larvæ have hard heads and well-developed thoracic legs. They and the adult beetles feed upon leaves, and often cause great damage to field and garden crops. One species—the Colorado beetle (*Doryphora decemlineata*)—is well known on account of its injuries to potato crops in North America. The pretty little asparagus beetle (*Crioceris asparagi*) is another member of this family, which also includes the curious tortoise-beetles (*Cassida*). The latter frequent thistles, wild mint, and other plants, and look more like scale insects than beetles.

We now come to a group of beetle families which are often spoken of collectively as the sub-order Heteromera. In all the species the tarsi of the front and middle legs are five-jointed, while those of the hind-legs are four-jointed. The family *Tenebrionidæ* includes the cellar beetle (*Blaps mucronata*), which shares with the cockroach the popular name of "black beetle." Another member of the same family is the well-known mealworm—the larva of *Tenebrio molitor*. The family *Rhipiphoridæ* is represented in Britain by the curious *Metoecus paradoxus*, the larva of which feeds as a parasite upon wasp grubs. The family *Meloidæ* includes the well-known oil beetles of the genus

Meloë. Reference has already been made to the remarkable hypermetamorphosis which these insects undergo and to their parasitic life in the nests of bees. To this family also belongs the European blister beetle or "Spanish fly" (*Lytta vesicatoria*).

Four other families constitute the group, or sub-order, Rhynchophora. These insects, known popularly as weevils, are distinguished from all other beetles by their four-jointed tarsi and by the elongation of the head to form a snout or rostrum. The *Anthribidæ* and *Brenthidæ* are mostly confined to the tropics, but the *Curculionidæ* are numerous in all parts of the world. The rostrum is always distinct, sometimes very long—as in the case of the nut-weevil (*Balaninus nucum*). The larvæ are always white, fleshy grubs, usually without legs. Both they and the adult beetles are vegetable feeders. They attack all kinds of plants in a great variety of ways, and are often very injurious. The apple blossom weevil (*Anthonomus pomorum*), which destroys the flower buds of apple trees, occurs wherever the apple is grown. Other species, such as the corn and rice weevils (*Calandra*), feed upon stored grain. The bark-beetles (*Scolytidæ*) differ from the other weevils in the slight development of their snout and in their more cylindrical form. The females make tunnels between the bark and wood of trees and lay their eggs therein; while the larvæ feed upon the soft layer immediately beneath the bark. When full-fed they pupate at the end of their burrows. Some species, such as the pine bark-beetle (*Hylurgus piniperda*), do damage in the adult state to the shoots of trees.

The family *Stylopidæ* includes a few small insects which are generally regarded as aberrant beetles. The adult males have broad hind-wings which fold lengthwise,

the fore-wings being represented by small, twisted processes; but the females are blind and grub-like. During the early stages of development both sexes live within the body of some other insect, usually a bee or a wasp. The male ultimately becomes a free-flying insect as above described, but the female remains a parasite throughout life. She produces an enormous number of minute six-legged larvæ, and these swarm among the hairs of the unfortunate host-insect, which thus becomes a source of infection to her kind.

Order XIV.—Mecoptera.

This order includes the single family of the scorpion-flies (*Panorpidæ*). These insects, which are found in all parts of the world, have biting mouth-parts, the mandibles being inserted at the tip of a kind of beak. The antennæ are long, slender, and many-jointed. The wings are long and narrow, with many cross nervules; but there are a few wingless species. The males of many species have the last two or three abdominal segments curiously developed. They are carried over the back like the tail of a scorpion, whence the popular name of the group. Metamorphosis is complete. The larvæ, which live in rotten wood, resemble caterpillars but have eight pairs of prolegs. Both they and the adults are carnivorous.

Order XV.—Trichoptera.

The caddis-flies were formerly included among the Neuroptera; but their structure is very distinct, and suggests affinity with butterflies and moths. The wings and body are covered with hairs. When at rest the fore-wings are brought together like a roof above the hind-wings, which fold up like a fan. There is a fold of membrane,

PLATE XIV

Swallow-tail Butterfly (*Papilio machaon*)

Goliath Beetle (*Goliathus giganteus*) from West Africa, compared with a Seven-spot Ladybird (*Coccinella septempunctata*)

called the *jugum*, at the base of each wing, by means of which the two wings of each side are united during flight. In adult caddis-flies the mandibles are obsolete, while the two pairs of maxillæ unite with the labrum to form an imperfect sucking apparatus. The antennæ are long and slender with many joints. The larvæ are the case-making "caddis worms," which have biting mouth-parts and feed for the most part upon vegetable substances. The perfect insects are often nocturnal in their habits, and make little use of their wings. The order is represented in all parts of the world.

Order XVI.—Lepidoptera.

Moths and butterflies may be distinguished from all other insects by the minute, over-lapping scales which cover their wings and bodies. The mouth-parts are modified to form a sucking tube, or proboscis, which has already been described (page 43). The neuration of the wings is mainly longitudinal, but a few cross nervules are usually present. The larvæ are always caterpillars, usually with five pairs of prolegs. They have powerful mandibles, and subsist upon the leaves or wood of plants, although a few species feed upon stored goods, or substances of animal origin, such as wool, wax, and feathers. The pupa is often enclosed in a cocoon formed by the larva; but in the case of most butterflies no such protection is provided. The popular division of Lepidoptera into "butterflies" and "moths" is misleading, butterflies being more nearly related to the higher moths than these are to the lower. In the three lowest families of moths the two wings of each side are united by a jugum, like those of caddis-flies. In most other moths the hind-wing is provided with a bristle—the *frenulum*—which hooks into a kind of strap on the underside of the fore-wing. In butterflies, the

wings are not united in any way. Further, the antennæ of butterflies are more or less clubbed at the tip, while those of moths, despite their great diversity of form, usually terminate in a point. In a general way, therefore, we may say that a scale-winged insect with clubbed antennæ, but without a frenulum, is a "butterfly," while all others are "moths." The order Lepidoptera has been divided into many families, only a few of which can be mentioned.

The *Micropterygidæ* form the lowest family of moths, with striking affinities to the caddis-flies. They are very small insects, and differ from all other Lepidoptera in their imperfectly suctorial mouth-parts. Small mandibles are recognisable, while in the pupa these jaws are large, and serve to bite a way out of the cocoon. The caterpillars have eight pairs of prolegs, and feed in damp moss, or mine into leaves. The well-known swift moths (*Hepidlidæ*) are likewise of lowly origin. Their mouth-parts are greatly reduced, no food being taken in the perfect state. The larvæ burrow in the soil, and feed upon the roots of plants.

The day-flying moths known as burnets (*Zygænidæ*) have the wings joined by a frenulum, and a well-formed sucking trunk. The larvæ are stout and cylindrical, usually with five pairs of prolegs, and feed openly upon the leaves of plants. The larva constructs a strong, elongate cocoon above ground, usually upon a grass stem.

The *Psychidæ* are a small family of moths whose females are wingless and grub-like. The larvæ make portable cases, in which the adult females remain throughout life. The males have well-developed wings and antennæ, and fly freely; but their mouth-parts are functionless.

The *Cossidæ* are rather large moths with abortive

mouth-parts, no food being taken in the adult state. The larvæ feed within the stems of plants, or in the wood of trees. The three British species are the goat-moth (*Cossus ligniperda*), the wood-leopard moth (*Zeuzera æsculi*), and the reed-moth (*Phragmatœcia castaneæ*).

The clearwings (*Sesiidæ*) are day-flying moths, with narrow wings, which are for the most part free from scales. Many of the species resemble Hymenopterous insects. The larvæ feed within the stems and wood of plants.

The *Tortricidæ* are a very large family of small moths. Many of the larvæ roll up the leaves of their food-plant; but other species feed within fruits, or give rise to gall formations. There are many British representatives, well-known examples being the green oak tortrix moth (*Tortrix viridana*), the codlin moth (*Carpocapsa pomonella*), and the pine-shoot moth (*Retinia buoliana*).

The *Tineidæ* are an even larger family of moths, most of which are very small. The wings are usually narrow and pointed, fringed with long and delicate hairs. The larvæ have very various habits. Some feed openly upon plants, others mine into the tissue of leaves, while not a few are destructive to stored goods. The clothes moths are familiar representatives of this family.

The *Pyralidæ* include the beautiful "pearl moths," so-called because their wings exhibit a peculiar pearly sheen, but most of their congeners are unattractive in appearance. The larvæ usually live in concealment, feeding between rolled-up leaves, or upon dried vegetable substances. Those of the flour moth (*Ephestia kühniella*) work much havoc in mills and granaries where they feed upon the meal, sometimes blocking the machinery with the webs which they spin. Allied species, such as the fig moth (*Ephestia ficella*), infest groceries. This family also

includes the wax moths which infest the nests of bees, where the larvæ feed upon the combs and refuse.

In the small family of hook-tip moths (*Drepanulidæ*) the larvæ have only four pairs of prolegs—the pair usually found on the last segment of the body being absent.

The eggar- and lappet-moths (*Lasiocampidæ*) are usually rich brown or yellowish in colour, and are densely covered with hairs and scales. There is no frenulum at the base of the hind-wings. The larvæ, which have ten prolegs, are also very hairy. The pupa is enclosed in a compact cocoon composed of silk worked up with hairs from the larva's body. The family is represented in all parts of the world except New Zealand. Well-known British examples are the lackey (*Clisiocampa neustria*), the drinker (*Odonestis potatoria*), and the lappet (*Gastropacha quercifolia*).

The tussock-moths (*Lymantriidæ*) are also densely scaled insects, with tufted larvæ; but a frenulum is nearly always present. Familiar examples are the vapourer moth (*Orgyia antiqua*), in which the female is wingless, and the brown-tail and gold-tail moths of the genus *Porthesia*. Other members of this family are the black-arches moth (*Psilura monacha*) which, in Germany, is a serious forestry pest, and the gipsy moth (*P. dispar*), which has worked great havoc in North America since its introduction from Europe some forty years ago.

The tiger-moths (*Arctiidæ*) are conspicuous insects with brightly coloured wings. The common tiger (*Arctia caja*) is probably better known than any other British moth. Its larva is the familiar "woolly bear" which feeds upon the stinging nettle and other plants. This family is represented in all parts of the world.

The family of the owl-moths (*Noctuidæ*) includes an enormous number of species, mostly with dusky wings

and nocturnal habits. In some cases, however, the hind-wings are brightly coloured—as in the common red under-wing moth (*Catocala nupta*). The larvæ have usually five pairs of prolegs, though in some species there are only two or three pairs. The adult moths rest during the daytime upon fences or tree trunks. The family, which comprises upwards of 8000 known species, is represented in all parts of the world. Perhaps the best-known British example is the cabbage moth (*Mamestra brassicæ*), whose caterpillars are exasperating pests.

The puss-moths, prominents, and their allies (*Notodontidæ*) are found throughout the world, except in New Zealand. The larvæ are usually without prolegs on the hindmost segment of the body. They are often very curious in form, and assume most remarkable attitudes when alarmed. Some species form a cocoon, while others bury themselves in the ground before changing to the pupa.

The hawk-moths (*Sphingidæ*) are robust, swift-flying insects which are represented in all parts of the world. The privet hawk-moth (*Sphinx ligustri*) is a well-known British species. In this family the caterpillars have always ten prolegs, and usually a spine or "tail" at the posterior end of the body. The pupa stage is passed underground, within an earthen cell or cocoon.

The large family *Geometridæ* comprises the carpets, pugs, and their allies. Their caterpillars are known as "loopers." They have usually only two pairs of prolegs, these being on the tenth and last segments.

The family *Bombycidæ* includes the true silk-moths. The common "silkworm," the larva of *Bombyx mori*, is perhaps better known than any other caterpillar. From the cocoons spun by these insects the silk of commerce is chiefly obtained. The family is well represented in the East, but sparsely in Africa and tropical America. An

allied family (*Eupterotidæ*) includes the European "processionary" moth (*Cnethocampa processionea*).

The family *Saturniidæ* includes some of the largest known moths, such as the Indian atlas moth (*Attacus atlas*). There is only one British representative—the emperor moth (*Saturnia pavonia*). In this family the pupa is always enclosed in a dense silken cocoon, which in some cases is commercially valuable.

The remaining families of Lepidoptera comprise the species which are known popularly as butterflies.

The skippers (*Hesperiidæ*) are stout-bodied insects which are found in all parts of the world, except Greenland and New Zealand. There are eight British species. All six legs are well developed in both sexes. The caterpillar spins a slight silken cocoon before changing to the pupa.

The blues, coppers and hairstreaks (*Lycænidæ*) have all six legs well developed in both sexes, except that the front tarsi are shortened in the males. The caterpillars are short and hairy, somewhat like wood-lice in shape. The pupa is also clothed with short hairs or bristles. It is usually attached by a cremaster (page 18) to a silken pad, and is often girdled by a silken thread. A closely allied family, the *Lemoniidæ*, in which the fore-legs of the males are greatly reduced and useless for walking, comprises an enormous number of brightly coloured species, most of which are indigenous to tropical America. The only British representative is the Duke of Burgundy fritillary (*Nemeobius lucina*).

The *Libytheidæ*—often called snout butterflies because their elongated palpi project beyond the head like a snout—have a wide geographical range, but are not found in Australia. A single species (*Libythea celtis*) occurs in Europe, though not in Britain.

The swallow-tails (*Papilionidæ*) are a very large family of handsome insects which abound in tropical countries. The six legs are fully developed in both sexes, while the wing neuration differs from that of all other butterflies. The larva is cylindrical, never hairy, but often with a curious retractile scent organ behind the head. The pupa, which has two projecting tubercles or "nose-horns," is fixed to a silken pad by its cremaster and kept upright by a silken girdle fastened to a stem of the food-plant. The British swallow-tail butterfly (*Papilio machaon*) is still common in some of the fen districts of the eastern counties. The scarce swallow-tail (*Papilio podalirius*) and the Apollo (*Parnassius apollo*) have both been captured in this country, but are not indigenous. This family includes the enormous bird-winged butterflies (*Ornithoptera*) of the Indo-Malayan region.

The *Pieridæ*, or "whites," are allied to the swallow-tails, but have a characteristic wing neuration. Moreover, the larvæ are more or less hairy, while the pupa has only one "nose-horn." The large cabbage butterfly (*Pieris brassicæ*), the brimstone (*Gonopteryx rhamni*), and the clouded yellow (*Colias edusa*) are well-known examples of this family, which is represented in all parts of the world.

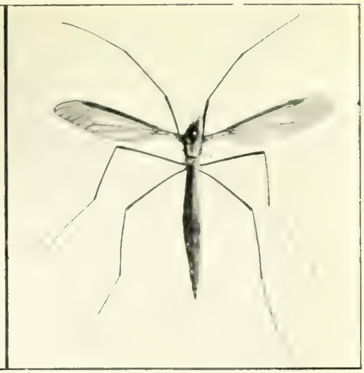
The *Nymphalidæ* are the largest and most dominant of the butterfly families. In both sexes the fore-legs are useless for walking. The larvæ vary greatly in form, being spiny or hairy in many genera, though smooth in others. The pupæ, which often display metallic areas, and thus merit the name "chrysalis," have two "nose-horns"; but they hang head downward from a silken pad, and are never girdled. The *Nymphalidæ* are usually divided into eight sub-families, only two of which are represented in Britain. The *Satyrinæ* comprise the meadow-browns and their kindred, while the *Nymphalinæ*

include our fritillaries and admirals, as well as the famous purple emperor (*Apatura iris*). Both these sub-families have a world-wide distribution. The *Brassolinæ* are large, robust insects found only in tropical America. The *Morphinæ* are confined to tropical America and the Indo-Malayan region. Some of the New World species have brilliant blue wings, and are among the most beautiful of all butterflies. The four remaining sub-families include a very large number of species, many of which are known to be distasteful to insectivorous creatures. The majority are conspicuously coloured. The *Danainæ* are represented in all the warmer regions of the world, and range far north in America, though not in Europe; the *Acræinæ* occur in tropical America, Africa, India and Australia; while the *Heliconiinæ* and *Ithomiinæ* are confined to Tropical America.

Order XVII.—Diptera.

The true flies, which constitute this order, may be distinguished from all other winged insects by the reduction of the hind-wings to stalked knobs called balancers or halteres, the fore-wings alone being used for flight. In some families there is a membranous hood, called the *squama*, behind each wing. The mouth-parts are modified for piercing and sucking (page 45). The antennæ vary greatly in different families, but are rarely conspicuous. The legs are usually slender, often spiny, while the tarsi have five segments. The wings are membranous with not more than seven longitudinal nervures, and a few cross nervules. Diptera undergo a very complete metamorphosis, the larva being always eruciform, often a legless maggot. The pupa is variable in form. It is rarely enclosed in a cocoon, but lies buried in the ground,

PLATE XV



Great Ox Gad-fly (*Tabanus bovinus*): magnified

Crane-fly or "Daddy-Longlegs" (*Tipula oleracea*)

Forest-fly (*Hippobosca equina*): magnified

"Sheep-tick" or "Ked" (*Melophagus ovinus*): magnified

A Hover-fly (*Syrphus pyrastri*): magnified

Sleeping Sickness Tse-tse Fly (*Glossina palpalis*): magnified

floats in the water, or is enveloped in a puparium formed from the last larval skin. There are two sub-orders, both of which include many families.

Sub-Order 1.—Orthorrhapha.

In this sub-order the larva has a hard head, while the skin of the pupa or puparium splits longitudinally down the back, allowing the perfect insect to escape. There are a large number of families which fall into two groups.

In the first group the antennæ are slender and thread-like, and relatively long. It includes, among other families, the gall-midges (*Cecidomyidæ*), whose larvæ burrow into plant tissues and often give rise to galls; the fungus-midges (*Mycetophilidæ*), whose larvæ feed in vegetable refuse and fungi; the true midges (*Chironomidæ*), and the gnats (*Culicidæ*), whose larvæ are aquatic. The family of crane-flies or daddy-longlegs (*Tipulidæ*) also belong to this group. Their larvæ—well known as "leather-jackets"—feed upon the roots of plants and are notorious pests.

In the second group of families the antennæ are relatively short, usually with only three segments. Among them are the gad-flies (*Tabanidæ*), the females of which suck the blood of horses and cattle, although the larvæ live in damp earth, and feed upon snails, slugs, and beetle-grubs. The larvæ of the robber-flies (*Asilidæ*) also live in damp earth, while the imagines prey upon other insects. The bee-flies (*Bombyliidæ*) resemble humble-bees in appearance, and suck nectar from flowers. Their life-histories are imperfectly known, but in some species the larvæ are parasitic upon bee-grubs, while others devour the eggs of locusts.

Sub-Order 2.—Cyclorrhapha.

In this sub-order the larva is a maggot without a distinct head-capsule, while the anterior end of the puparium is pushed open like a circular lid when the perfect insect escapes. The flies have short, three segmented antennæ, the third segment, which is much the largest, bearing a long bristle.

The hover-flies (*Syrphidæ*) are a very large and important family. Many of them resemble wasps and bees to a remarkable degree. The perfect insects feed chiefly upon pollen, but the larvæ of many species prey upon aphides, while others live in fungi or refuse. The *Conopidæ* are another family of brightly coloured wasp-like flies which, in their larval state, are parasitic upon Hymenopterous insects.

The bot-flies (*Œstridæ*) are hairy, bee-like insects whose mouth-parts are quite obsolete. Their larvæ live as parasites in the bodies of large animals. Some species inhabit the nasal cavities, others the food-canal, while others—like the warble-flies (*Hypoderma*)—live just beneath the skin of their host. The pupa state, however, is always passed in the ground.

The enormous family *Muscidæ* includes many well-known forms, of which the common house-fly (*Musca domestica*) is typical. It has been split up into several groups, or sub-families. One of these includes the bristly Tachinid flies (*Tachininæ*), whose larvæ are parasitic upon caterpillars; another, the grey flesh-flies (*Sarcophaginæ*); while a third comprises the house-flies, blow-flies, and their near allies (*Muscinæ*). The common grey flesh-fly (*Sarcophaga carnaria*) is viviparous—as are many of its congeners. The larvæ are produced alive, and placed by the parent upon suitable food. Among the *Muscidæ*,

the African tse-tse flies, of the genus *Glossina*, are also included.

The family *Anthomyidæ* comprises a large number of species which resemble small house-flies. Their larvæ usually feed upon decaying animal or vegetable substances, but some attack living plants. Among the latter the cabbage root fly (*Phorbia brassicæ*) is a well-known pest.

The spider-flies (*Hippoboscidæ*) include the wingless "sheep-tick," or "ked" (*Melophagus ovinus*), and the forest-fly (*Hippobosca equina*). These insects and their congeners are viviparous, and spend their lives on the bodies of mammals or birds, whose blood they suck. The allied *Nycteribiidæ* live parasitically upon bats; while the family *Braulidæ* includes the minute, wingless insect known as the bee-louse (*Braula cæca*), which infests hive-bees, being found most commonly upon the queen.

ORDER XVIII.—Siphonaptera.

The fleas, which make up this order, are allied to the Diptera, but differ from them in certain marked characters. They are always wingless, while their bodies are flattened laterally. The antennæ usually lie in little pits on either side of the head; the mouth-parts are modified for piercing and sucking; while the eyes are simple. The legs are long and powerful, specially adapted for leaping. Adult fleas are blood-sucking parasites, but the soft-skinned, active larvæ live in, and feed upon, dust. The pupa is enclosed in a slight silken cocoon. There are two distinct families of fleas: the *Pulicidæ* and the *Sarcopsyllidæ*. The former are represented in all parts of the world, the largest species being *Hystrichopsylla talpæ*, which infests moles and field mice. The latter—the so-called "jiggers"—are confined to the tropics. After pairing, the females burrow into the skin of small animals and man, giving rise to painful

tumours; but the larvæ, on hatching, escape from the host's body.

Order XIX.—Hymenoptera.

This order includes the saw-flies, ichneumons, ants, wasps and bees—insects with two pairs of membranous wings. Except in some tiny species the wings of each side are united during flight by a series of minute hooks, on the anterior margin of the hind-wing, which engage with a corresponding fold in the fore-wing. The mandibles retain their biting function; but the other mouth-parts are often adapted for licking or sucking. The first, or basal, segment of the abdomen is more or less closely united with the thorax—the characteristic "waist" of such an insect as an ant or a hornet coming not *between* the thorax and the abdomen, but *behind* the first abdominal segment. The females are provided with elaborate ovipositors, which in many families are modified into poison-injecting stings. Hymenoptera undergo a complete metamorphosis, the larva being always a variant of the eruciform type, while the pupa is free, usually enclosed in a silken cocoon. Two sub-orders are recognised.

Sub-Order 1.—Symphyta.

In this group, which includes the saw-flies, the abdomen is not basally constricted to form a "waist." The ovipositor of the female is adapted for cutting or boring but never for stinging. The larvæ, except in those species which burrow into the tissues of plants, resemble the caterpillars of butterflies and moths; but they have more than five pairs of prolegs. There are three families.

The stem saw-flies (*Cephidæ*) are small, slender insects

whose larvæ burrow into the stems of plants. The corn saw-fly (*Cephus pygmæus*) infests wheat, but is not sufficiently common in this country to be injurious, though on the Continent it is sometimes the cause of much damage.

The large wood-wasps (*Siricidæ*) are represented in Britain by two species: the giant wood-wasp (*Sirex gigas*) and the steel-blue wood-wasp (*S. juvencus*). These insects and their allies are characteristic of the northern forest regions. By means of her powerful ovipositor, the female inserts her eggs into the wood of trees, in which the larvæ burrow and feed.

The true saw-flies (*Tenthredinidæ*) are mostly of moderate size. The ovipositor of the female consists of two saw-like plates by means of which cuts are made in the tissues of leaves and stems for the reception of the eggs. The caterpillar-like larvæ have many prolegs—sometimes eight pairs. Most of them feed openly on leaves, but a few species live in galls. The pupa is enclosed in a tough, silken cocoon, which is generally buried in the ground, but sometimes attached to the food-plant. This family is characteristic of the northern hemisphere, being poorly represented in tropical and southern countries.

Sub-Order 2.—Apocrita.

In this sub-order, which comprises the vast majority of Hymenopterous insects, the abdomen is markedly constricted behind the first segment to form a waist. In some families the ovipositor becomes a sting. In all cases the larva is a white, legless grub which depends for its sustenance upon the instinctive provision made by the parent, or—in the case of social species—upon the

food brought to it by the "workers" of the community. The sub-order includes many families, among which the following are most important.

The gall-wasps (*Cynipidæ*) are small, dark-coloured insects, most of which lay their eggs in the tissues of plants, and give rise to galls. Some of the species, however, are parasites, while others are inquilines—*i.e.* they lay their eggs in galls which have been induced by other species.

The ichneumons make up the large families *Ichneumonidæ* and *Braconidæ*. The females lay their eggs in the bodies of caterpillars, upon which the larvæ feed as parasites. Some species, which attack wood-burrowing grubs, possess exceptionally long ovipositors, and thrust these implements through the solid timber in order to reach their victims. The full-fed larvæ leave the body of their host, and spin cocoons, before changing to pupæ.

The *Chalcididæ* and *Proctotrypidæ* are enormous families of minute insects, most of which are parasitic in their early stages of development. Many species attack caterpillars. Others lay their eggs in galls, or in the nest-cells of the higher Hymenoptera, and their grubs prey upon the contained larvæ. Many of the *Proctotrypidæ* are egg parasites—*i.e.* they lay their eggs in those of larger insects. The *Chalcididæ* include a remarkable group of gall-forming species known as fig-insects, of which more anon.

The ruby wasps (*Chrysididæ*) are remarkable for their brilliant blue, green, or crimson hues. They are often called "cuckoo wasps," because the females lay their eggs in the nest-cells of other Hymenopterous insects, where the Chrysid grub feeds upon the contained food or upon the rightful occupant.

The ants (*Formicidæ*) are characterised by the nodular form of the waist and by their elbowed antennæ. They are found in all parts of the world, but are most abundant in tropical countries. They live together in communities which comprise wingless, imperfectly developed females (workers), in addition to winged males and females of the ordinary type.

The *Mutillidæ* are sometimes called "solitary ants." Their bodies are usually covered with brightly coloured hairs. Only the males are winged. There is one British species (*Mutilla europæa*), which lives in humble-bees' nests, where its larvæ feed as parasites upon the bee-grubs.

Three families of Hymenoptera are known as "digger-wasps." The *Scoliidæ* are abundant in the tropics, but only one small species occurs in Britain. The females burrow into the ground, where they lay their eggs upon beetle larvæ, thus providing food for their grubs. The *Pompilidæ* construct nests, usually by digging in sandy banks, and provision them with spiders. The *Sphegidæ* have similar habits, but prey for the most part upon caterpillars, though some take flies, crickets, and hard beetles. Both these families are abundant in all parts of the world, and are represented in Britain by numerous species.

The true wasps (*Vespidæ*) may be known by the fact that the fore-wings are folded longitudinally when the insect is at rest. There are two sub-families. In the solitary wasps (*Eumeninæ*) the shin or tibia of the middle leg has only one spine at the tip, and the claws of the feet are toothed. The species usually construct earthen nests, which they store with caterpillars and other insects. Some of the species form incipient colonies by building their nests close together. Among the social wasps (*Vespinæ*) the tibia of the middle leg has two spines at

the tip, and the claws of the feet are simple. With few exceptions, these insects dwell together in social communities, which comprise workers, males and females.

The bees (*Apidæ*) are distinguished from all other Hymenoptera by the feathery hairs which clothe their bodies, and by the great enlargement of the basal segment of the tarsus (p. 55). They vary greatly in their form and life-histories. Most of the genera are made up of solitary species; but the higher bees are pre-eminently social in their habits. All bees feed upon nectar and pollen, and are thus more intimately associated with flowers than any other insects.

CHAPTER VI

THE SENSES OF INSECTS

BEYOND the dust and din of cities, the summer air vibrates to the pressure of insects' wings. Go where you will this sound assails the ear, telling of innumerable organisms in rapid motion; so that in country places the least observant must at times be made keenly alive to insect activity. The mind pictures vast populations passing on their way, unconscious, or at least regardless, of human existence, versed in a science of which the very rudiments are unknown to us. On these occasions it is natural to speculate upon the senses of insects, the organs which minister to them, and the degree in which they may resemble or differ from our own.

Such inquiries are very fascinating, but they are also very illusory. If one might live for a day the life of such an insect as the hive-bee, the mystery which surrounds its being would be at once swept aside. As it is, we are obliged to grope in the dark. For while at first thought it may seem an easy matter to decide whether an insect is endowed with this sense or that, and to point to the organs by means of which its impressions of external happenings are derived, in reality there are difficulties in the way which often prove well-nigh insurmountable. Nevertheless, it is possible to hazard shrewd guesses, based upon the discoveries of anatomists, and the observations of those who have patiently watched living insects, and thus, by analogy, to form some conception of the relations

of these marvellous creatures to the world in which they live.

It will be convenient to consider first the nervous system of the insect, and the organs which minister to it—the receivers and wires, so to speak, by means of which impressions are taken up and transmitted to the centres of perception. We have already seen that the central nervous system differs in a marked degree from that of a vertebrate animal: that it consists of twin nerve-cords, which extend along the ventral floor of the body, and connect a series of paired knobs, or ganglia. Typically, there is a nerve-centre (paired ganglia) to each segment, a condition which is most nearly realised in certain larvæ, and adult insects of the order Aptera. But in all other adult insects the ganglia tend, as it were, to draw together, while the nerve-cords frequently become one. In the head, the ganglia are always united to form two masses. The first is the brain proper, which innervates the eyes and antennæ, and directs the movements of the legs and wings; the second may be regarded as a kind of supplementary brain which governs the activities of the mouth-parts.

The consolidation or linking up of the originally separate nerve-centres of the thorax and abdomen is most marked in highly developed insects. "In the stag-beetles" (writes Professor Carpenter) "the three nerve-centres of the fore-body are distinct, though the second and third are nearly united, but the number of nerve-centres in the hind-body is reduced to three. In bees there are only two nerve-centres in the thorax, and five in the hind-body. In gad-flies the three thoracic nerve-centres are fused into a single mass; those of the abdominal chain, though still distinct, are moved close together and far forward. In chafers and in house-flies and their allies all the nerve-centres behind

the sub-œsophageal ganglion (*i.e.* the supplementary brain) are united into a single mass situated in the fore-body. Such fusion of nerve-centres may be said to result in concentration of individuality; for where a nerve-centre is present in each segment, each segment is to some extent capable of independent life."

From the central system, nerves radiate to all parts of the body. These may be either sensory or motor, the former transmitting impressions (or calls) inward from a sense-organ, the latter conveying impulsive stimuli (or answers) outwards to the muscles, glands, &c. The most wonderful of all the special sense-organs—indeed, the most wonderful of all the structures of the insect—are the compound eyes. Their anatomy varies greatly in detail, but our present purpose will be served by the following brief description. If we examine the surface (or cornea) of these eyes with the aid of a microscope, we see that it is divided into a multitude of minute areas, commonly six-sided, known as facets. The number of facets varies with the size of the eye. Thus, the eye of the little "silver-fish" has as few as twelve; while it has been calculated that in the eye of the cockroach there are 1800, of the house-fly 4000, of the goat moth 7000, and of the swallow-tail butterfly 17,000. Some dragon-flies have 20,000, and some hawk-moths as many as 27,000. Now each of these facets is the surface of a lens, and each lens is mounted upon a minute inverted cone, termed a crystalline cone, which in its turn connects at its tapering end with a nerve-rod. A crystalline cone consists of a group of sensitive visual cells in touch with the nerve-fibres, and each cone is optically separated from its neighbours by means of dark pigment. The whole eye is intimately connected with the brain, of which, indeed, it may almost be said to form an offshoot.

Insects never have more than one pair of compound

eyes; but in some instances these eyes are divided, so as to give the appearance of a pair on each side of the head. This is the case with the "whirligig" beetles of the family *Gyrinidæ*, which swim upon the surface of the water. One isolated half of each eye is directed upwards, the other down, so that the insect is able to search for its aquatic prey, and at the same time to watch for any danger which may threaten from above. Still more remarkable are the eyes of certain male may-flies, in which one part of the eye forms a pillar facceted at its summit, while the other part occupies a more normal position at the side of the head. Male two-winged flies of the genus *Bibio* also have divided eyes; while in other Diptera—none of which are found in Europe—both the eyes and antennæ are carried on long, horn-like projections from the sides of the head.

In addition to their conspicuous compound eyes, many insects possess ocelli, or simple eyes, commonly three in number. Each ocellus is a small polished lens, beneath which a cup-shaped mass of pigment cells forms a retina, which is connected by nerves with the brain. Certain larvæ have a little group of similar eyes on each side of the head; but others, especially such as are surrounded by an abundance of food and live in darkness, have no eyes at all.

We have already seen that in three families of the Orthoptera specialised ears are situated either on the front leg below the knee, or at the base of the abdomen; while somewhat similar structures are found on the fore-legs of stone-flies, termites, and ants; also on the tarsi, or feet, of some beetles. The external openings of the ears in long-horn grasshoppers and crickets are usually apparent as two curved slits in each tibia at a point where this joint is somewhat swollen. Each slit opens into a chamber,

the inner wall of which forms a tympanum or "drum," which is in connection with air-spaces and nerve-endings. In some species, however, the tympanum is not in a covered chamber, but at the bottom of an oval depression. Among short-horned grasshoppers an auditory apparatus, comprising one large drum, is found on each side of the first abdominal segment; while in many two-winged flies a circular drum, connected with nerve-endings, is situated in a cavity beneath the base of each wing. The structure of all these strangely placed organs is very complex; but those who have examined them admit that they are admirably adapted to receive and transmit sound-waves; and there can be no doubt that they serve the sense of hearing. There are also organs situated in the antennæ of many insects, notably the males of certain gnats and midges, the function of which is thought to be auditory.

In addition to specialised eyes and ears, insects possess an enormous number of "end-organs"—minute pits, pegs, hairs, and cones of very varied form—which are connected with sensory nerves. These may be found on all parts of the body, but they are most numerous in the neighbourhood of the mouth, and on the joints of the antennæ. We must not forget that the chitinous covering of the insect, which we have likened to a suit of armour, is a hard, dead substance. It has no nerves distributed in it, but is pierced with minute pores through which the end-organs communicate with the nerves. The precise functions of the various structures are naturally very difficult to determine, but it is thought that while many of those on the mouth-parts serve a sense of taste, others on the antennæ and palpi are organs of touch and smell. There is also reason for thinking that many insects without specialised ears detect sound-waves by means of end-organs situated

in the antennæ. In the case of the hornet, it has been estimated that there are 13,000 sensory "pits" on each antenna; in the blow-fly 17,000; while in the male cockchafer the number is nearly 40,000.

Our knowledge of the senses of insects depends almost entirely upon experimental evidence, although in the case of specialised eyes and ears something may be inferred from the structure of the organs. The simple eyes of an insect are of very short focus, and there is no power of adjustment. Thus, if the image on the retina is to be "sharp," as a photographer would say, the object must be at a definite distance from the lens; and as the lens is usually strongly convex, this distance must be small. The simple eyes, in fact, are exceedingly short-sighted. Those of a caterpillar, for example, are of such a focus that their owner can see the surface upon which it crawls, and the food which it is eating; but objects a few inches away probably appear dim and unsubstantial. Indeed, in the case of most insects which possess them, simple eyes are probably more serviceable in distinguishing light from darkness than in forming images.

The compound eyes of adult insects have for many years formed a subject for debate among naturalists. It is admitted that they are scarcely if at all inferior to the eyes of a vertebrate animal in the delicacy and intricacy of their structure; yet their physiology has proved a vexed question. After much discussion and endless experimenting, the theory put forward early in the last century by Johannes Müller is still generally accepted. This supposes that an exceedingly fine ray of light passes through each lens, or facet, and down the channel formed by its corresponding cone and rod—all oblique rays being absorbed by the surrounding dark pigment. Thus, while each element of the compound eye is responsible for only

a very small part of the visual field, namely, that which is exactly opposite the facet concerned, one continuous image of surrounding objects—made up, as it were, of countless fragmental images—is formed upon what may be termed the retina. Müller's conception of insect vision is usually spoken of as the "mosaic theory," because the separate images formed by the individual facets are believed to combine on the retina in much the same way that little pieces of stone or marble are fitted together to form a mosaic pavement. Clearly the large, globular eyes of such an insect as the dragon-fly must command a very wide range of vision. Their owner must be able to see in almost all directions at once without moving its head. But our knowledge of the actual power of sight among insects is extremely meagre. The experiments of Lord Avebury (better known as Sir John Lubbock) and others have shown that some insects, at least, are undoubtedly able to distinguish between colours, and that they show a preference for some colours over others. Thus, hive-bees commonly choose blue flowers, white butterflies prefer white flowers, while yellow butterflies appear to alight most frequently upon yellow flowers. Indeed, there is small room for doubt that an insect's perception of colour enables it to find a particular kind of blossom, or to recognise a suitable mate; although we shall see that the majority of insects seem to rely chiefly in these matters upon the sense of smell. But there is little evidence to show that the sight of insects is at all keen, or that they possess a clear perception of form; nor is this surprising when we are told that the compound eyes, like the ocelli, are of fixed focus. In a word, the compound eyes appear to be especially adapted for transmitting sensations of light and motion to the brain; and although the limit of vision probably varies in different

species, there is reason for thinking that no insect can see an object at a greater distance than six feet.

The fact that many insects are able to make audible sounds lends strong support to the assumption that they can hear, quite apart from the evidence of the specialised ear-structures which many species possess. These sounds are instrumental rather than vocal, most of them being produced by the vibration of a membrane, or by the friction of one part of the body against another part, the process in the latter case being termed "stridulation." Stridulating organs are possessed by many beetles, by several ants, and by a few moths, but, as might be expected, they attain their greatest perfection among those families of the Orthoptera which possess well-developed ears. The so-called "song" of the male cicada is produced by the rapid vibration of two membranes, or drums, situated at the base of the abdomen, each drum being worked by a special muscle. The wings of many Hymenoptera and Diptera vibrate with so much speed and regularity that a definite note is produced. This wing tone, in the case of a hive-bee in vigorous flight, is *a* in the treble clef, while it may drop to *e* if the insect is fatigued or heavily laden. But the buzzing or humming of insects is by no means always due to the vibration of the wings. Flies, bees, dragon-flies, and some beetles are able to produce at will a similar sound by means of vibratile membranes situated just within the spiracles. All bee-keepers are aware that the emotions of the hive find expression in the sounds made by its inmates, while some have ascribed a wide range of meaning to the various notes which are produced. Thus, Mr. T. W. Cowan, quoting from Stahala, says that "if in winter one taps the hive and a loud 'Huumm' is heard, it is a sign that the bees have their queen and sufficient food. The

loud 'Dzi-dzi' is heard when both stores and bees are dwindling. The loud 'Dziiiiii' will be heard when they are too cold. 'Huuum' is produced by queenless stocks both in summer and winter. A loud 'Wuh-wuh-wuh' is only heard when breeding is going on, but never when the hive is queenless, or has an unfertilised queen. When water is being collected they produce a loud 'Usiiir,' and young bees playing outside the hive utter a loud 'Shu-u-a,' but as a swarm leaves the hive 'Shiusi' is produced, the normal sound of a swarm being 'Ssssss.' 'Brr-brr-brr' is heard when drones are being expelled, and the 'Tu-tu-tu' is known to every bee-keeper as the sound produced by the just-hatched young queen, which is answered by 'Qua-qua-qua' of those queens still enclosed in their cells. Besides these there are some dozen other sounds produced, differing both in tone and intensity."

Similarly, the expert naturalist is able to recognise species of grasshoppers and crickets merely by listening to their chirping, and Dr. S. H. Scudder has expressed some of these "songs" in musical notation; while it is said that in these insects the frequency of stridulation increases with the temperature, and that "the correlation between the two is so close that it is easy to compute the temperature from the number of calls per minute, by means of formulæ." Nor is there room for doubt that insects which lack specialised ear-structures are able to hear and interpret the varying sounds produced by their own species. Mayer, a distinguished American naturalist, found that the hairs on the beautifully plumed antennæ of a male gnat "vibrate in unison with the notes of a tuning-fork within the range of sounds emitted by the female. The longer hairs vibrate sympathetically with the graver notes, and the shorter hairs with the higher ones." Another observer (Will) placed a female long-horn

beetle in a closed box on a table; and, at a distance of about four inches, a male of the same species. The latter appeared to be quite unconscious of the female's proximity until she began to produce, by stridulation, a low shrill note, when he immediately extended his antennæ, and moved them round and round as if endeavouring to discover the direction whence the sound proceeded. Experiments have also been made with ants, bees, and wasps, and it has been found that while these insects take no notice whatever of ordinary sounds, they immediately become alert, with extended antennæ, when their own sounds are imitated by means of a fine file rubbed upon a quill. It should be added, however, that they soon appear to detect the imposition, show signs of alarm, and endeavour to escape.

Such facts lead us to conclude, as Lord Avebury has said, that the auditory organs of insects are "situated in different parts of the body, and there is strong reason to believe that even in the same animal the sensitiveness to sounds is not necessarily confined to one part. In the cricket, for instance, the sense of hearing appears to be seated partly in the antennæ, and partly in the anterior legs." Nevertheless, while insects are undoubtedly affected by the sounds of their own world, they are strangely indifferent to the far louder noises which are produced by mankind. One may shout or sing, or even fire a gun, in close proximity to a bee or a beetle; yet provided that the insect is not directly affected by air currents, it evinces no sign of alarm.

We generally assume that insects are able to taste their food; but whether they possess a gustatory sense in any way equivalent to our own is open to question. We know that many caterpillars are fastidious in the choice of their diet; that certain moths levy their toll of nectar

upon one kind of flower to the exclusion of all others; that ants and bees can detect certain inodorous substances which have been mixed with honey. These are well-established facts; but they do not prove that insects can taste. Half-grown caterpillars will often starve rather than renounce their ancestral diet; yet the same kinds of caterpillars, when just hatched, will readily adapt themselves to a quite different food. This is not always the case, but it is sufficiently common to suggest that their fastidiousness in later life is largely a matter of habit, possibly based upon the sense of smell, but having little or nothing to do with that of taste. Again, the preference which certain insects display for a particular kind of flower is not necessarily the outcome of deliberate choice. In many instances it is governed by the insect's mouth-parts, which may be too long or too short, or in some way unfit to probe successfully more than a limited number of the blossoms which it may encounter. For the insect and flower have been evolved through long ages of mutual dependence, and have become inseparable. The one matches the other as a key fits a lock; and if the former is quick to perceive where its welcome is sure, and to pass over blooms whose sweetness is reserved for other visitors, its guiding senses are probably those of sight and smell.

The French savant Forel mixed morphine and strychnine with honey and offered it to bees. They refused the concoction after a first mouthful. Similarly, Will accustomed wasps to visit a particular spot for powdered sugar, and then replaced the sugar by alum. The wasps ate some of the latter, soon detected the change, and began rubbing their mouth-parts to cleanse them. To quinine also they evinced an obvious dislike. But the evidence of these and other experiments tends to show that the insect gains its impressions of what it is eating

most readily when the substance concerned is biting or astringent in property. In other words, the insect appears to *feel* its food rather than *taste* it. This is precisely what one would be led to infer from a knowledge of insect anatomy. The sense of taste, as possessed by mankind and the higher animals, implies the possession of certain nerves in intimate association with those which convey olfactory impressions to the brain. People who lack the sense of smell are also deficient in the sense of taste. For some reason the nerves of taste will not perform their functions unless they are *en rapport* with the nerves of smell. If we compress the lobes of the nostrils so that breath can only be drawn through the mouth, and proceed to eat some sugar or honey, we find that no matter how closely we may concentrate our mind upon our palate, our ability to detect sweetness is in abeyance. But if, still holding the nose, we substitute salt or alum for a sweet substance, the nerves of the mouth at once convey definite impressions to the brain. It is evident, however, that these impressions are more nearly akin to a sense of touch, than to one of taste. We seem to *feel* the contact of the salt or alum with the palate very much as we should feel a drop of vitriol applied to the back of the hand.

By some such means, perhaps, an insect is able to determine in a rough and ready fashion the nature of a substance which it has taken into its mouth; but its powers of discrimination seem to be limited and incongruous. Will found that ants refused honey with which a very little glycerine had been incorporated; but when Forel offered a concoction of honey and phosphorus to ants, they ate it greedily, to their own undoing. In similar circumstances man would be able to detect the phosphorus, but not the glycerine.

That the sense of smell is very acute among insects cannot be doubted. Indeed, those who have studied insects most closely agree that their behaviour is largely governed by impressions transmitted to the nerve-centres from olfactory end-organs. The latter are often present upon the palpi, but they are generally most numerous upon the antennæ, which may be regarded as a pair of highly efficient noses—though not, of course, to the exclusion of other functions for which they may be fitted. If we dip a glass rod into strong-smelling liquid, such as acetic acid or turpentine, and bring it near to an insect, we shall notice that the antennæ are immediately moved vigorously about; while they may subsequently be cleaned by being drawn through the mouth, as though to purge away the last vestiges of the pungent vapour. Many insects, such as flesh-flies, carrion-beetles, and flower-frequenting species of all kinds, detect the whereabouts of their favourite food by means of their antennæ; and those individuals in which these organs have been destroyed or mutilated are liable to perish by starvation in the midst of plenty, for they become quite indifferent to the odours which guide their uninjured companions. In some insects the olfactory sense is well-nigh incredibly keen. Thus, all the ants of a given colony are believed, not without reason, to possess a characteristic nest-smell, by means of which they recognise one another and detect the presence of strangers; while other communal insects, such as bees and wasps, appear to be similarly gifted, for they are quick to welcome friends, even after months of separation, and never fail to drive away intruders. Even more wonderful is the manner in which other insects, especially certain moths, track down their mates by means of their sense of smell. The antennæ of the male are often marvellous structures, plumed or branched, and

beset with many hundreds of end-organs which, by a system of nerves, are brought into close association with the brain. The female has no such special sense endowments. She may, indeed, exhibit signs of great simplification, such as the complete absence of wings. But she is provided with a scent-producing gland, from which a peculiar perfume streams out upon the breeze, and is carried over the countryside. This perfume is usually so delicate as to be quite outside the range of human perception, yet it is detected at a great distance by the males, which are guided by it to their mates. Conversely, the males of some butterflies and moths—possibly of other insects as well—possess scent glands on the legs and wings, which are believed to render their owners more charming to the opposite sex. On all counts, therefore, we are justified in the belief that the perceptual world of the insect—its inner realisation of material things—is chiefly built up from impressions which are derived through its sense of smell.

The sense of touch, probably the oldest of all the senses, is manifestly possessed by insects ; while in some it appears to be highly developed. The antennæ of blind cave insects are exquisitely sensitive to tactile stimuli; while some of the most careful observers of ants and their ways are agreed that these insects are able to communicate with one another by a kind of touch-language. An ant that chances upon a supply of food starts homeward, and meets a fellow worker on the way. A mutual stroking and patting of antennæ follows, and then the two ants go back to the food in company. In a short time the news is passed on to other members of the community, and they in their turn hurry to the prize.

The tactile end-organs of insects appear to take the form of minute hairs or bristles, each in connection with

a nerve. As might be expected, they are most numerous upon the antennæ and palpi, but they are also found over the whole surface of the body. Yet while insects are keenly alive to the contact of foreign bodies, they seem for some inscrutable reason to be completely immune from the sensation of pain. It is possible to pass a pin through the body of a sleeping moth without awakening it; while a wasp which had lost the whole of its abdomen was observed to partake of syrup with evident gusto—the syrup forming a steadily growing drop at the point where the food-canal had been severed. Still more remarkable is the case of a dragon-fly, mentioned by the Rev. Theodore Wood, which by an unlucky chance had been deprived of its abdomen. This insect not only devoured, in quick succession, some thirty blue-bottle flies, but finally disposed in the same way of its own severed body. Hundreds of similar instances might be cited to prove the complete *sang froid* evinced by mutilated insects. Possibly the loss of certain organs or appendages may give rise to a sensation of discomfort or inconvenience; but there is no clear evidence to support even this contention. Some wasps, whose wings had been struck off by a butcher's knife, seemed quite unaware of their loss. They whittled away at the fragments of meat with which they wished to fly off, evidently bent upon reducing the weight, but apparently quite unaware that their inability to rise in the air was the real cause of their trouble.

While the evidence of common observation, backed by the testimony of science, suggests that many insects possess at least "five senses," we have no means of judging to what extent these may correspond with our own. That they differ remarkably in range can scarcely be doubted; while there is reason for believing that insects are endowed with special senses at the nature of

which we can only guess. The abortive hind-wings, or halteres, of Diptera are very mysterious. They are abundantly supplied with nerves, and it is significant that their loss entails upon the insect an inability to maintain its equilibrium in the air. It may be, therefore, that these organs minister to a "sense of balance." Again, insects are extremely responsive to slight variations of wind, temperature, moisture, and atmospheric pressure, while many blind insects can distinguish between light and darkness. The possibility of hearing light must not be overlooked. Quite recently an instrument has been invented by Mr. Fournier D'Albe, of Birmingham University, whereby light is rendered audible to the human ear; and it is not unreasonable to suppose that insects may be keenly conscious of ether waves to which our grosser senses fail to respond.

The case for these hypothetical senses of insects has never been more forcibly put than by Lord Avebury, who, as the result of ingenious experiments, became convinced that ants can see the ultra-violet rays which are invisible to our eyes. "Now, as every ray of homogeneous light which we can perceive at all, appears to us as a distinct colour, it becomes probable that these ultra-violet rays must make themselves apparent to the ants as a distinct and separate colour of which we can form no idea, but as different from the rest as red is from yellow, or green from violet. The question also arises whether white light to these insects would differ from our white light in containing this additional colour. At any rate, as few of the colours in nature are pure, but almost all arise from the combination of rays of different wave-lengths, and as in such cases the visible resultant would be composed not only of the rays we see, but of these and the ultra-violet, it would appear

that the colours of objects and the general aspect of nature must present to animals a very different appearance from what it does to us. These considerations cannot but raise the reflection how different the world may—I was going to say must—appear to other animals from what it does to us. Sound is the sensation produced on us when the vibrations of the air strike on the drum of our ear. When they are few the sound is deep; as they increase in number, it becomes shriller and shriller; but when they reach 40,000 in a second, they cease to be audible. Light is the effect produced on us when waves of light strike on the eye. When 400 millions of millions of vibrations of ether strike the retina in a second, they produce red, and as the number increases the colour passes into orange, then yellow, green, blue, and violet. But between 40,000 vibrations in a second and 400 millions of millions we have no organ of sense capable of receiving the impression. Yet between these limits any number of sensations may exist. We have five senses, and sometimes fancy that no others are possible. But it is obvious that we cannot measure the infinite by our own narrow limitations."

CHAPTER VII

THE BEHAVIOUR OF INSECTS

When we say that an organism is alive, we imply that its behaviour differs from that of an inanimate object, such as a stone. The latter is inertly submissive to the forces which play upon it, whereas a living organism (or being) manifests a certain awareness with respect to its surroundings, coupled with an ability to choose between expedients and to act spontaneously. Among plants and the more lowly animals this mysterious quality of animation is quite independent of a nervous system; nor are we justified in believing that it involves any degree of consciousness. There is no ground for supposing that these beings know and perceive, although many of their movements are astonishingly purposeful in the sense that they promote a particular end. A plant growing in an ordinary room turns towards the window, and when moved from one position to another is able to readjust itself in relation to the source of light; while in a subsequent chapter we shall see that the responsive movements of some insectivorous plants are even more rapid and definite. Again, we may watch through the microscope the extremely simple aquatic animals known as Protozoa. The amœba, for example, is a minute speck of colourless jelly very similar to the white corpuscles which abound in the blood-vessels of the higher animals; but unlike them it is a free unicellular being—not an insignificant item in a composite structure. The amœba is a law unto itself. It creeps actively about

in search of food, selects from a mass of algæ one or two kinds, feeds by flowing round them, and ultimately discards the indigestible residue. Moreover, it is manifestly affected by changes of temperature, being inert at freezing-point, but becoming more and more active as the water acquires a genial warmth. An allied form, the "slipper-animalcule," is impelled through the water by vibratile hairs (cilia) which beset the surface of its body. It is capable of three adjustments to its surroundings. Normally it moves forward; but if it encounters an obstacle, its cilia immediately reverse their motion, with the result that the creature moves backward for a short distance. It then stops, revolves on its axis through the fraction of a circle, and once more glides forward. If it again collides, it repeats the manœuvre of backing and turning until at last its course is clear.

Such facts as these show us that plants and the lowest animals, although they have no recognisable brains and nerves, are nevertheless well able to maintain their place in the great world of which they form a part. We are also led to conclude that sensitiveness, or irritability, as it is often called, is a fundamental property of protoplasm—the living, jelly-like substance from which all organisms are built up. Any change in the environment of a plant or an animal, whether it be of temperature, light, or atmospheric pressure, is termed a stimulus, while the corresponding adjustment of the organism is known as its reaction or response. We must not assume, however, that an organism is susceptible to all the innumerable variants of heat, light, moisture and what not which play upon it, or that the same stimulus always evokes the same kind of response. On the contrary, each being, whether plant or animal, is attuned to a particular set of stimuli, to which it responds in certain definite ways.

Although these reactions may be, and often are, quite independent of a nervous system, there can be no question that such a mechanism confers a distinct advantage upon its possessor by rendering the responses more speedy and effective. A plant, by turning towards the window, evinces its ability to distinguish light from darkness; but its response is far less rapid than that of an insect, whose eyes enable it to detect on the instant the slightest shadow passing across its field of vision. Nevertheless, the response in each case is a simple reflex act in which consciousness plays no part.

These reflex acts are often spoken of as tropisms—a convenient word, culled from the Greek, which we may translate "turnings." They form the basis of all insect behaviour. Thus, an insect may be phototropic as it turns to or from the source of light; thigmotropic as it courts or is repelled by the touch of a foreign body; anemotropic as it faces or turns from the prevailing wind. Many other tropisms are recognisable. But the essential point to bear in mind is that these "turnings" are inevitable on the part of the being concerned, no matter what the result. A moth rushes headlong into the flame of a candle and sears its wings. It does this again and again until its power of flight is destroyed, and it falls maimed and dying upon the table. The moth is attuned, so to speak, to a low intensity of light. In common with other nocturnal animals it is repelled by strong sunlight, but responds by active movement to the softened radiance of approaching night; these adjustments being in exact accordance with its needs. That it meets its death in the flame is a mere contretemps, due to the impetus of its rapid flight and to the fact that artificial luminaries are abnormal to its environment. Other animals that move slowly react to the counter stimulus of increasing

heat as they approach the light, and thus escape destruction.

The behaviour of many insects is diametrically opposed to that of night-flying moths. Most butterflies, for example, attain the zenith of their activity in strong sunlight, while their movements are arrested by the shadow of a passing cloud. Again, the majority of insects shrink from contact. This often proves a valuable trait, conducive to safety; but whether valuable or the reverse, the response always occurs when the stimulus is forthcoming. On the other hand, a few insects are known to be positively thigmotropic. They court touch. Their whole being responds to the stimulus. Among them is a small moth which is accustomed to squeeze itself into crevices under loose bark or elsewhere. Now at first thought one might suppose this to be a mere light-shunning reaction, calculated to effect the creature's concealment. But the German experimenter Loeb has proved otherwise. He put some of the moths into a box one half of which was covered with opaque material, the other half with glass. On the floor of the box he arranged several sheets of glass, raising them upon small blocks just enough to allow a moth to squeeze its way beneath. As a result it was found that the moths congregated beneath the sheets of glass, even when exposed to full sunlight, in preference to the dark corners of the box, which were easily accessible, and where they would have been concealed from their enemies. Clearly this moth's habit of hiding, though apparently purposeful, is really a simple reaction to the stimulus of pressure. It is useful only so long as the creature's surroundings remain normal.

But while simple responses to appropriate stimuli meet the needs of plants and lowly animals, and have their place even in the conduct of man himself—as when the

hand recoils from heated metal—they do not alone suffice for the requirements of creatures so highly organised as insects. All those who have watched living insects are aware that they perform more or less complex actions, either for their own immediate good or for the benefit of their offspring: and that these actions, while they are often so remarkably successful as to appear rational, are in reality quite independent of consciousness, experience, or tuition. This kind of behaviour is called instinctive. A given stimulus sets going a connected series of responses, each of which inevitably calls forth its successor. Thus the female brimstone butterfly seeks a buckthorn leaf, to which she fixes her egg. She cannot taste the leaf nor can she have any foreknowledge of the needs of an offspring which she will never see. Her action is purely instinctive, evoked by some kind of stimulus—probably the distinctive odour of the requisite plant. Again, many moths, which spin their cocoons within a leaf, first securely fastens the leaf to the twig with a wrapping of silk; yet they can have no conception of the risk of falling that neglect of this precaution would involve. Still more remarkable is the behaviour of a small weevil known as *Rhynchites betulæ*, which rolls up birch leaves in order to provide food and shelter for its young. Beginning at the edge of the leaf, not far from the stalk, the insect makes a long s-shaped cut to the midrib. She then ascends the leaf for a short distance, and makes a similar cut from the other side of the midrib to the opposite edge. These cuts have been examined by mathematicians, who (to quote Dr. David Sharp) have extolled them as being conducted on highly satisfactory principles. In a word, they are exactly those which are needed to overcome the leaf's tendency to spring back, and thus to render the rolling most easy of accomplishment. Subsequently, the insect

Plate XVI

1

2

3 4 5

Successive stages in leaf-rolling by the Birch Weevil (*Rhynchites betulæ*)

twists the severed portion into a compact screw or funnel, within which the eggs are deposited, finally closing the orifice by tucking in the tip of the leaf. All these operations are performed in a characteristic manner, with little or no variation, just as if the weevil had served a long apprenticeship to leaf-rolling and had acquired unerring proficiency in the art. Yet the eggs, which hatch in the rolled-up leaf, produce blind, legless grubs, which when full-grown fall to the ground, where they change to pupæ and lie hidden throughout the winter; so that the perfect weevils, which come forth in the early summer and creep up the birch stems, cannot possibly have seen a rolled-up leaf, much less have witnessed the method of construction. Experience and memory manifestly play no part in the insect's behaviour. It is purely instinctive.

The nervous mechanism whereby a complicated instinct is performed has been slowly built up from small beginnings through the agency of natural selection, exactly as the outward form and coloration of the insect have been adapted to its needs and environment. In other words, an insect is not only equipped at birth with an elaborate system of nerves and sense-organs, but it inherits also a complete set of stereotyped habits. These are often performed with such unerring precision that they appear rational in a high degree. But in face of unaccustomed circumstances most insects are completely nonplussed. A species of digger-wasp (*Sphex*) habitually drags its victim—a long-horn grasshopper—by one antenna. The great French naturalist, J. H. Fabre, cut off both antennæ, with the result that the wasp, after vain efforts to secure its customary hold, abandoned its prey. Yet it might easily have dragged the grasshopper by one of its legs. Another instance which illustrates this inflexibility of instinct may be quoted from the writ-

ings of the same observer. It relates to a mason bee (*Chalicodoma muraria*), which constructs a nest of from six to ten cells, using as material "a calcareous clay, mixed with a little sand and kneaded with the mason's own saliva." Each cell, when complete, is stored with nectar and pollen. Then an egg is laid, and a roof is added. Finally, the bee covers the whole group of cells with a dome-shaped mass of its usual mortar. Now as these nests are often built upon pebbles, they may readily be moved from one place to another without injury; and by taking advantage of this fact Fabre was able to demonstrate by experiment that the bee, although she can return unerringly from a distance of four kilometres to her chosen nesting site, is quite unable to recognise her own work. Further, he found that the operations of building, storing and egg-laying succeeded one another with automatic precision, without regard to circumstances. "Here is a mason bee" (he writes) "at work on the first course of her cell; in exchange I give her one not only completed, but half full of honey, which I stole from an owner who would speedily have laid an egg there. What will the mason do with this munificent gift which spares her the labour of building and storage? Leave her mortar, of course, lay an egg, and close all up. Not at all, the animal finds our logic illogical. The insect obeys an inevitable, unconscious impulse. It has no choice as to what it shall do—no discernment as to what is and is not desirable—but glides, as it were, down an irresistible slope prepared for it beforehand to bring it to a determined end. The facts still to be stated affirm this strongly. The bee, which is building, and to which I offer a cell ready made and full of honey, will not give up building for that: she is following her trade as mason, and once on that tack, led on by unconscious impulse,

she must needs build, even if her labour be superfluous and contrary to her interests. The cell I give her is certainly quite complete in the opinion of its own constructor, since the bee from whom I subtracted it was finishing the store of honey. To touch it up, and, above all, to add to it is useless and absurd. All the same the bee which is building will build. On the orifice of the honey store she lays another layer of mortar, then another and another, until the cell is actually a third beyond its usual height. Now the task is done—not as well indeed as if the bee had continued the cell whose foundations she was laying when the nests were exchanged, but certainly in a way more than enough to demonstrate the irresistible impulse which drove the builder on. Then came the storing, likewise abridged, for otherwise the honey would overflow by the union of the stores of two bees. Thus the mason bee, which is beginning to build, and to which one gives a cell completed and filled with honey, alters nothing in the order of her work. First she builds and then she stores; only she shortens her labours—instinct warning her that the height of the cell and quantity of honey are beginning to assume proportions too great."

The concluding words of this passage introduce us to another aspect of insect behaviour. We perceive that the instincts of an insect, inflexible in the main, may nevertheless prove capable of some adjustment. They are not, as is sometimes stated, absolutely "blind." Indeed, an action can be regarded as purely instinctive in its initial performance only. Thereafter, the factor of experience must be taken into account; and it is by no means easy to determine what part of a given action may be due to instinct and what to memory. One point, however, is clear. Instinct does not grow into intelli-

gence, but is gradually replaced by it in proportion as the special need of the creature demands such an exchange. In the words of Professor Lloyd Morgan, we may say that "where these congenital (or inborn) modes of response take the form of instinctive behaviour, there is supplied a general plan of action which intelligence particularizes in such a manner as to produce accommodation to the conditions of existence." Thus, it comes to pass that in many highly specialised insects with concentrated nerve-centres, pure instinct becomes less important, and consequently less perfect, being replaced by a corresponding measure of intelligence derived from the experience of the individual. This fact is well illustrated by Mr. Tickner Edwardes's description of a young hive-bee's early essays as a forager. "The industry of the bee in nectar-gathering" (he writes) "has always been a stock subject for wonder, and it is commonly supposed that she is born with full instinctive capabilities for her task. A little observation, however, soon tends to upset this theory. The work of foraging has to be learnt step by step, like every other species of skilled work in hive-life. The young bee, setting out on her first flight, has all the will to do well, and her imitative faculty is strongly developed; but she seems to have very little else. Her first experiences are a succession of blunders. She appears not to know for certain where to look for the coveted sweets, and can be seen industriously searching the most unlikely places—crevices in walls, tufts of grass, or the leaves of a plant instead of its flowers. The fact that the nectar is hidden deep down in the cup of the flower, beyond its pollen-bearing mechanism, seems to dawn upon her only after much thought and many fruitless essays."

To sum up then, we may say that the behaviour of

Plate XVII

Protective Resemblance: *Catocala sponsa* with wings expanded, and in resting attitude on oak bark. Britain

insects is derived from simple reflex acts in which consciousness plays no part. These constitute the raw material, so to speak, from which more elaborate combinations, called instincts, have been built up through the agency of natural selection, and transmitted as a kind of self-acting nervous mechanism from one generation to another. Broadly speaking, instincts are unaccommodating, being performed in the same way by every member of the species without regard to circumstances. But in all insects, especially in the higher forms, there is a tendency for instinct to be replaced by the fruit of individual experience—*i.e.* by memory. Thus, while instinct undoubtedly dominates the behaviour of insects, it fails to account for every detail. In some of their actions insects display a measure of intelligence. Beyond this we cannot go. Between intelligence and rationality there is a great gulf fixed, and no evidence exists to show that it has been crossed by insects. Even ants, according to the experiments of Lord Avebury, display profound stupidity in face of novel emergencies which might easily be circumvented by abstract reasoning of the simplest kind.

CHAPTER VIII

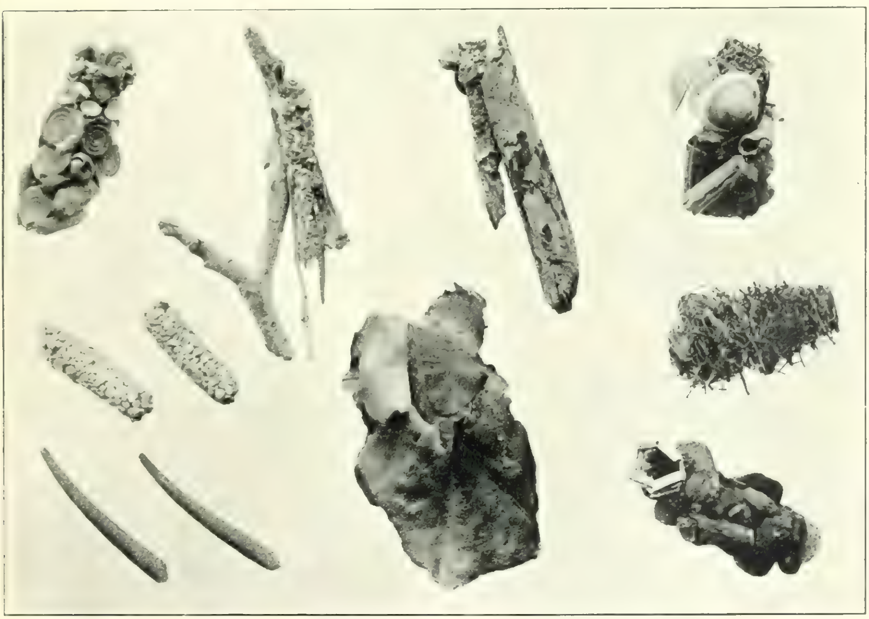
PROTECTIVE RESEMBLANCE

The colour of an organism is often due to the presence in its semi-transparent tissues of substances which play a part in some physiological process. Thus, leaf-green is the colour of chlorophyll—the substance which enables plants to build up living matter from the gases and salts which they absorb from air and water. Similarly, the aquatic larvæ of certain midges (appropriately called "blood worms") are red because their blood contains the respiratory pigment hæmoglobin, which takes up oxygen from the air and transmits it to the tissues. Blood-red and leaf-green may therefore be regarded as non-significant in so far as the relation of the organ to its environment is concerned. But many animals display a wealth of superadded colour which has an important bearing upon the life-history of the creature concerned. For instance, a common use of colour is to assist an animal in escaping from its enemies; and among insects we find numerous examples of this kind. Protective resemblance, as it is called, may be either general or special. In other words, it may consist in a mere similarity of the insect's colouring to its customary surroundings—to the background, so to speak, against which it is commonly seen; or the insect may be an actual reproduction, in both colour and form, of a definite object with which it is associated throughout life.

Instances of general protective resemblance are familiar to all who have observed insects in their natural haunts.

Plate XVIII

Lithinus nigrocristatus, from Madagascar. There are two beetles on the lichen-encrusted twig above



Protective cases formed by various species of Caddis-worm (*Trichoptera*)

Oft-cited examples are the moths which rest upon tree trunks during the daytime. Many of them have brightly coloured hind-wings; and if they contravene their nocturnal instinct and sally forth into the sunlight, they become at once objects calculated to attract hungry birds. But when seated upon a tree trunk in their customary attitude of repose, they are effectually concealed by the colours of their fore-wings, which harmonise with the rough surface of the bark. Other moths, such as the marvel-du-jour (*Agriopis aprilina*), have the fore-wings coloured so as to resemble lichen. Moreover, this particular type of colouring may be seen in many insects of other orders, among them being a wonderful beetle from Madagascar, known as *Lithinus nigrocristatus,* which can only be distinguished from a tuft of lichen after the closest scrutiny. In all such cases we notice that the sharp outline of the insect is obliterated by a cunning arrangement of dark and light tints; and this is of first importance, for no matter how closely the colouring of an insect may accord with its background, a tell-tale outline would detract from the concealing value of its colouring.

Turning from general to special protective resemblance, we find a bewildering array of examples. Perhaps the most convincing are the butterflies of the genus *Kallima*—the "leaf butterflies" *par excellence*—which are found in India and the Malay Archipelago. When flying in the full sunlight, with their wings flashing purple and orange, they are very conspicuous. But when they pitch upon the ground, or upon a twig, they are immediately transformed into brown and withered leaves. Experienced naturalists have been at a loss to discover the exact whereabouts of a *Kallima* butterfly, although they have actually watched it settle. This marvellous capacity for hiding is due chiefly to the leaf-like colouring of the wings beneath;

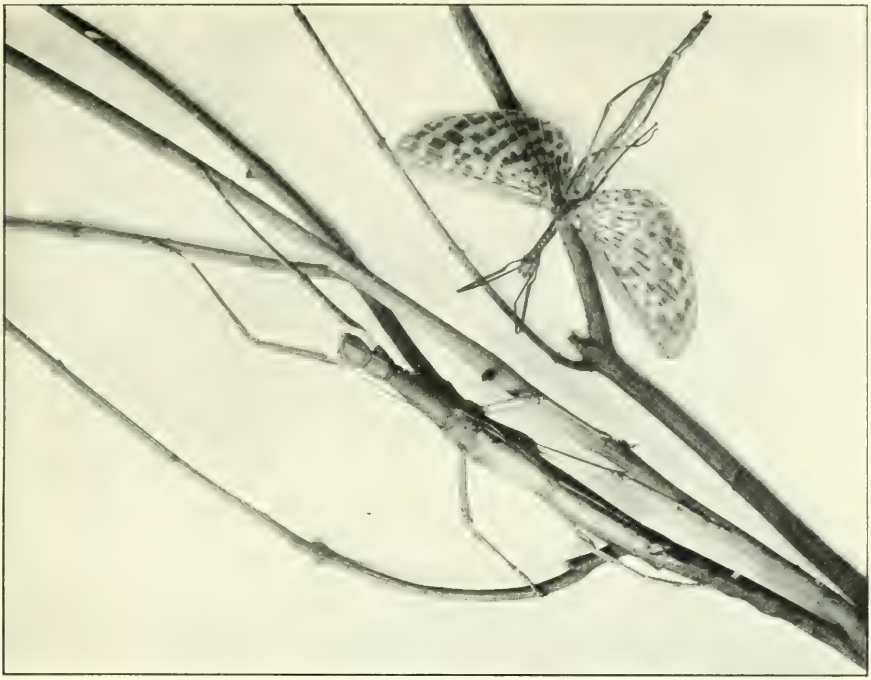
but the deception is heightened by the shape of the wings and the manner in which they are held when the insect is at rest. The tip of the fore-wing is pointed, and the hind-wing has a short tail like a leaf-stalk; while, when the butterfly settles, the wings are brought together over the back, the head and antennæ being concealed between them. Moreover, just as dead leaves vary in colour, so a corresponding variety of tinting is seen on the butterflies' wings. Again, small holes are often bitten in leaves by caterpillars; and this possibility is anticipated, so to say, in the butterfly by a spot, clear of scales, which exists in each fore-wing. When the insect is at rest these spots are brought exactly opposite one another, with the result that the transparent membranes produce the effect of a small, irregular puncture.

Many other butterflies and moths simulate dead leaves in various stages of decay; while some—such as our own green hair-streak butterfly (*Thecla rubi*)—resemble living foliage. But the most wonderful "green leaf insects" belong to the genus *Phyllium*, of the family *Phasmidæ*. They are found only in the tropics of the Old World, and have a peculiar penchant for island life. The females are much more leaf-like than the males because the tegmina, or fore-wings (usually reduced or absent in other members of the family), are large and foliaceous. In both sexes, however, the body is greatly flattened, while its colour is a vivid green which, when submitted to spectral analysis, is said not to differ from that of the living leaf. It is even recorded that "Mr. J. J. Lister, when in the Seychelles, brought away living specimens of *Phyllium;* and these, becoming short of food, nibbled pieces out of one another, just as they might have done out of leaves, . . . but confined their depredations to the leaf-like appendages and expansions." Still more remarkable is the fact that the

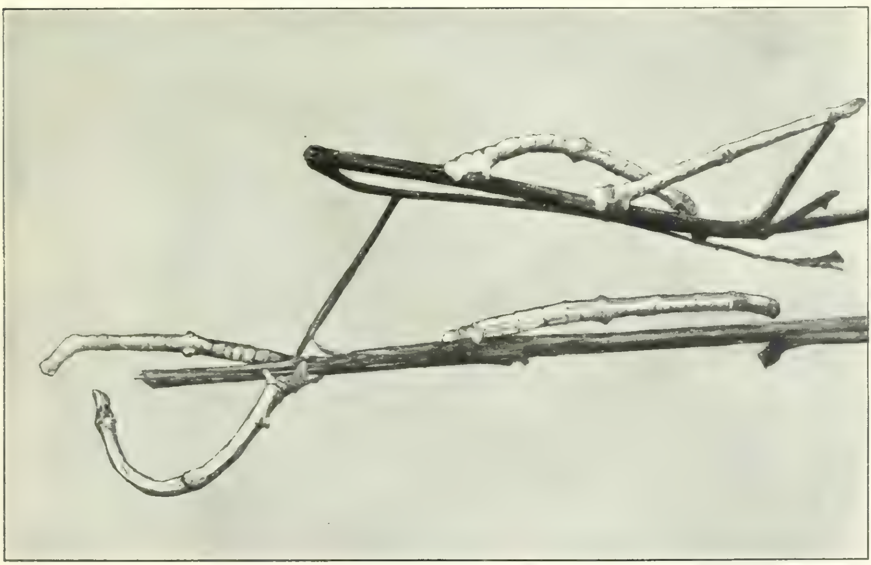
PLATE XIX

Protective Resemblance: *Phyllium crurifolium* (two females). Ceylon

PLATE XX



Tropical "Stick" Insects (Phasmids)



Stick-like Caterpillars of Swallow-tail Moth
(*Ourapteryx sambucaria*)

eggs of these insects bear a close structural resemblance to the seeds of plants.

All other Phasmids are endowed with a wonderful resemblance to twigs or stems. When wings are present, they fold up so tightly as to be scarcely noticeable when the insect is at rest; but many of the species fail to develop wings even in the adult state. The body and legs are nearly always ludicrously long and slender, while in some cases the effect is heightened by the presence of moss-like outgrowths, or strong spines, which have the appearance of thorns. When the sexes differ, the female is always more plant-like than her mate. Four or five species of stick insects, belonging to the genus *Bacillus*, are found in southern Europe, and one of these has been extensively reared in captivity in England during recent years. The temperature of an ordinary living room agrees admirably with these interesting "pets," which feed readily upon privet, and lay an abundance of eggs from which young hatch in due course. The manner in which these creatures pose among the twigs of their food-plant is an interesting object lesson in special protective resemblance, and enables the stay-at-home naturalist to appreciate the descriptions of those who have seen Phasmids in the tropics. The following word-picture by the late Professor Drummond has reference to a Central African species called by the natives "Chirombo." "Take two inches of dried yellow grass stalk, such as one might pluck to run through the stem of a pipe; then take six other pieces nearly as long and a quarter as thick; bend each in the middle at any angle you like, stick them in three opposite pairs, and again at any angle you like, upon the first grass stalk, and you have my 'Chirombo.' When you catch him, his limbs are twisted at every angle, as if the whole were made of one long stalk of delicate grass, hinged in

a dozen places, and then gently crushed into a dishevelled heap. Having once assumed a position, by a wonderful instinct he never moves or varies one of his many angles by half a degree. The way the insect keeps up the delusion is indeed almost as wonderful as the mimicry itself, and you may turn him about and over and over, but he is mere dried grass, and nothing will induce him to acknowledge the animal kingdom by the faintest suspicion of spontaneous movement." Tropical Phasmids are often of great size, some attaining a length of nine inches from head to tail, irrespective of their legs.

In the great family of "carpet moths" (*Geometridæ*) nearly all the caterpillars are stick-like in form and colour, and most of them assume an appropriate attitude when at rest. The majority feed at night; but when daylight comes they take a firm hold upon a twig with their two pairs of prolegs, and stretch out at an acute angle. To lessen the strain that this posture imposes upon the body, many of the species spin a delicate silken thread from their mouth to the stem on which they rest; and that considerable reliance is placed upon this support may be judged from the fact that if the thread be severed the creature falls back with a jerk. Among the commonest stick caterpillars are those of the swallow-tail moth (*Ourapteryx sambucaria*). They feed upon a variety of shrubs, trees and herbaceous plants, and are often very abundant in gardens; yet they are seldom seen because of their perfect resemblance to small brown twigs.

Some caterpillars rely solely upon their coloration for protection. That of the brimstone butterfly rests during the day in a nearly straight position on the upper side of a buckthorn leaf. It is fully exposed to view, yet it tones so perfectly with its background as to be practically invisible as a separate entity. Caterpillars

Caterpillars of Pine Beauty Moth (*Panolis piniperda*) resting among needles of Scotch Pine

Caterpillar of Puss Moth (*Cerura vinula*) in resting attitude

which feed upon grasses or the needle-like leaves of pine trees are commonly marked longitudinally with strongly contrasted colours. Those of the pine beauty moth (*Panolis piniperda*), for example, are striped with white and dark green, and fit their environment so perfectly that even an expert naturalist, with a full knowledge of what he is looking for, rarely discovers a specimen except by chance.

The colours of an insect often appear conspicuous when the creature is isolated from its customary surroundings; yet they probably blend perfectly with the particular setting in which Nature intended them to be seen. Thus, the large caterpillar of the privet hawk-moth (*Sphinx ligustri*) is bright green, with seven oblique white stripes bordered with purple on each side. If we see it for the first time in a cardboard box, the protective value of its coloration is incomprehensible. But the same caterpillar, when among the leaves of privet or lilac, is wonderfully concealed. Professor Poulton has pointed out that the purple-margined white stripes break up the surface of the caterpillar, and perhaps suggest the appearance of leaf shadows.

Protective colouring in nature is often enhanced by a subtle rendering of light and shade—a fact which has been emphasized by the American artist-naturalist, Mr. Abbott H. Thayer. The presence of an animal, even if its tints accord perfectly with the background, may be betrayed to its enemies by the sharpness of its outline, or by the shadow which it casts. Mr. Thayer reminds us that an artist, by the process of shading—*i.e.* painting in shadow—produces the appearance of relief, or solidity, upon his flat canvas; and he claims that Nature's protective colouring tends to promote an exactly opposite effect. Her shading aims at what we may term a paint-

ing out of shadows, the result being that the appearance of solidity is destroyed. To illustrate his theory in its bearing upon the colours of large animals, Mr. Thayer constructed models (replicas of which may be seen in the Natural History Museums of London, Oxford, and Cambridge) by means of which he proved that a bird which is dark on the back, shading through increasing paleness on the sides to white beneath, is far less conspicuous than one that is uniformly coloured—even though its tints may exactly accord with its surroundings. Both the dummy birds are covered with the same grey material with which the box is lined. One is otherwise uncoloured, and is rendered very conspicuous by the illumination of its back and the heavy shading of its under surface—thus showing that mere identity in the colour of an animal and its surroundings does not in itself afford protection. The other model is skilfully painted with a dark tint above, shading to white beneath, with the result that an effect of flatness and unreality is produced. At a distance of four feet it is invisible.

The principle of shadow neutralisation, or obliterative colouring, was recognised by Professor Poulton a number of years before Mr. Thayer formulated his theory. After describing the wonderful stick-likeness of the Geometrid caterpillars, he has the following passage: "In order that the resemblance may be complete, it is essential that the caterpillar should appear to grow out of the branch in a natural manner. The two pairs of claspers assist in producing this effect, for they partially encircle the branch, and appear to be continuous with it. Between the two pairs there is necessarily a furrow, where the body of the larva lies along the cylindrical branch. This furrow, which, if apparent, would greatly interfere with the resemblance, is rendered inconspicuous in the following

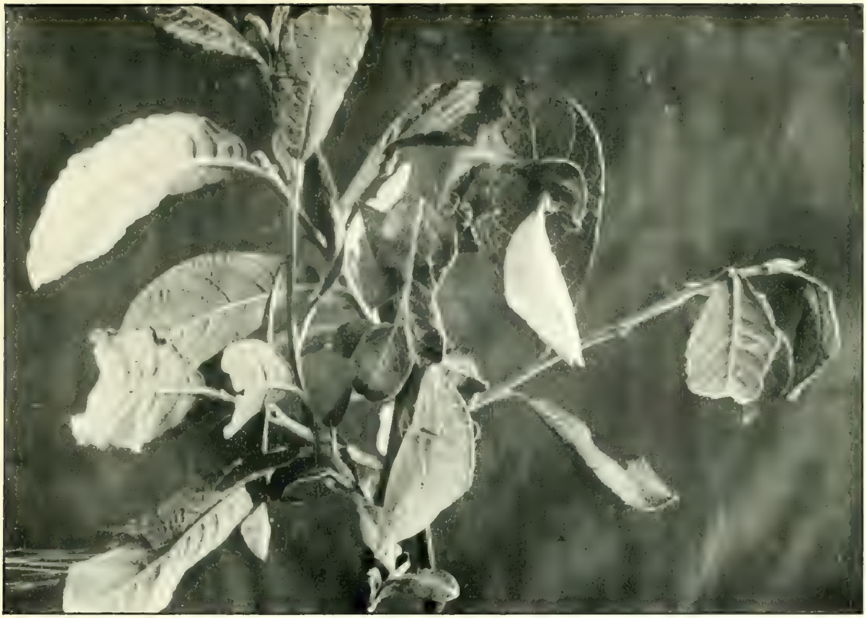
manner. The underside of the caterpillar is somewhat flattened, so that it is in contact with a small part of the circumference of the branch, and the furrow on each side is partially filled up, at any rate in certain species, by a number of fleshy tubercles. The shadow which would betray the furrow is also neutralised by the light colour of the tubercles."

Professor Poulton also emphasized, in the following passage, the protective value of appropriate shading in the case of the large green pupa of the purple emperor butterfly (*Apatura iris*), which closely resembles a leaf of its food-plant, the sallow. "The most extraordinary thing about this resemblance is the impression of leaf-like flatness conveyed by a chrysalis, which is in reality very far from flat. In its thickest part the pupa is 8·5 mm. across, and it is in all parts very many times thicker than a leaf. The dorsal side of the pupa forms a very thin sharp ridge for part of its length, but the slope is much more pronounced in other parts and along the whole ventral side. But exactly in these places, where the obvious thickness would destroy the resemblance to a leaf, the whole effect of the roundness is neutralised by increased lightness, so disposed as just to compensate for the shadow by which alone we judge of the roundness of small objects. The degree of whiteness is produced by the relative abundance of white dots and a fine white marbling of the surface, which is everywhere present mingled with the green. The effect is, in fact, produced by a process exactly analogous to stippling. The degree of lightness produced in this way exactly corresponds to the angle of the slope, which, of course, determines the depth of the shadow. By this beautiful and simple method the pupa appears to be as flat as a leaf which is only a small fraction of 1 mm. in thickness."

Doubtless a closer study of insects in relation to their surroundings will bring to light many similar examples of obliterative shading. There is, too, the possibility of optical illusion, consequent upon the relative intensity and arrangement of the markings on an insect's body or wings. Many dark-coloured moths, for example, have a very distinct white or pale spot in the middle of each fore-wing. At first thought this would seem to detract from the creature's disguise; but the reverse probably holds good. The eye is at once caught and held, as it were, by the conspicuous spots, and for this very reason fails to detect the less obvious outline of the insect.

Certain butterflies, when at rest with closed wings, have the appearance of flowers. A remarkable example is the familiar orange-tip (*Euchloë cardamines*). The upper surface of the wings is white, with black markings; while in the male only there is a large orange area at the tip of each fore-wing. When flying these insects are very conspicuous, but as soon as they settle among herbage they seem to drop out of existence; the reason being that the underside of the hind-wings, between which the fore-wings are folded in repose, are mottled with green and white in a manner which suggests an inflorescence, such as that of the plant called marsh valerian. That the orange-tip butterflies frequently settle upon or near blooms of this kind the writer can vouch from his own observations; and when the insect composes itself for a long rest, it tucks its body between its folded wings, and raises the latter in a characteristic manner—a habit which greatly enhances the protective resemblance. Several of our common blue butterflies look like the plantain heads and flowering grasses among which they roost; and when settling for the night, or in dull, windy weather, they invariably turn head downwards. Indeed,

PLATE XXII



Pupæ of Purple Emperor Butterfly (*Apatura iris*) hanging among leaves of Sallow

Orange-tip Butterfly (*Euchloë cardamines*) resting on inflorescence of Marsh Valerian

in almost all cases of special protective resemblance, we find that the most effective pose—*i.e.* that calculated to enhance to the full the concealing value of the insect's coloration—is the one which is habitually adopted. Of course this does not justify the assumption that insects have any knowledge of their appearance, or that they consciously take up appropriate attitudes: but it does lead us to conclude that the same principle of natural selection which has fashioned an insect's structure, has also modified its habit so that the one may accord with the other. The stick-like form of a caterpillar would be of little service if the creature lacked the instinct to pose in a stick-like manner.

This correlation of structure and instinct constitutes a wide field for investigation. It is not enough merely to know what a creature does; we want to find out also the reason for its actions—the bearing which they have upon the exigencies of its life. For instance, many butterflies—such as the grayling (*Satyrus semele*)—which rest upon the ground, have the habit of dropping suddenly after a short flight, and lying over on one side. This trick not only serves to throw the protective colouring of their wings into greater prominence, but also to minimise—it may be completely to cover—the shadow which the insect casts. The habits of an African butterfly (*Hamanumida dædalus*) are said to vary in different districts. In West Africa it rests with its wings folded above the back after the common manner of butterflies, in which position the tawny underside, which agrees with the general tone of the soil, is exposed to view. In South Africa, however, the same insect sits with its wings fully expanded, showing the white-spotted upper surface which resembles the colours of the rocks in that region. There is also much evidence to support the theory that

insects commonly settle upon surfaces with which their colours harmonise.

Perhaps the most curious case of protective resemblance coupled with an appropriate habit is that vouched for by Professor Gregory, and described in his work *The Great Rift Valley.* The insect in question is a species of *Flata*—a genus comprised in the family *Fulgoridæ.* It is found in British East Africa, and is dimorphic, a certain number of individuals being bright pink in colour, while others are bright green. The insects frequent the stems of plants, from which they suck the sap; and the order of their grouping is very remarkable. The pink ones sit upon the lower part of the stem, while the green ones take up positions above, towards the extremity. Moreover, the developing larvæ—which secrete long waxy filaments, and are quaint, fluffy objects quite unlike their parents—sit beneath the pink individuals at the lowest part of the stem. In this way the exact appearance of a spiked inflorescence, such as that of the foxglove, is produced. The fluffy larvæ look like seeds; the pink individuals resemble drooping flowers; while the green ones, higher up the stem, play the part of so many unopened buds. Professor Gregory was completely deceived by the first cluster which he saw, and attempted to gather it, when the mock flowers and buds jumped off in all directions. Subsequently he laid a trap for his botanist companion, Mr. Watson. "There were several similar clusters close by" (he writes), "and when Mr. Watson came up I pointed one out to him, and asked him if he had determined to what genus it belonged. He said he had not done so, but that he had seen it before growing in these woods. He attempted to pick it, and was as surprised as I had been at the result."

That many caterpillars, and the chrysalides of some butterflies, possess a limited power of adjusting their colours to suit their surroundings is beyond question. Professor Poulton obtained a large batch of eggs laid by one peppered moth (*Amphydasis betularia*) and divided them into two parts. One half of the larvæ were reared among green leaves and shoots exclusively, and became bright green without exception. The other larvæ were supplied with leaves growing upon dark brown twigs, and in nearly all cases they became dark brown, though about one or two per cent. took their colour from the leaves. More recently it has been found that the greenish or grey lichen-like marks which characterise certain caterpillars are influenced by the environment of the individual. When caterpillars of the scalloped hazel moth (*Odontoptera bidentata*) feed among lichen-covered twigs they develop the lichen-like patches, while those whose lot is cast among twigs on which no lichen is growing do not. Similar results have attended experiments with the large caterpillars of the lappet moth (*Gastropacha quercifolia*). Effects such as these are believed to be due to the stimulus of reflected light upon the nerve-endings in the skin. The change takes place slowly, and can only be accomplished two or three times in the lifetime of a caterpillar; while we shall see that the colour of the chrysalis is predetermined by the surroundings of the caterpillar prior to its final moult. Yet, as Professor Poulton has said, this is sufficient, for caterpillars wander but little during their period of growth, while chrysalides cannot wander at all.

In the case of the small tortoiseshell butterfly (*Vanessa urticæ*), Professor Poulton proved that the surroundings of the full-fed caterpillar determined the colour of the chrysalis. Briefly, a black environment gave rise to dark

pupæ, while white or gilded surroundings induced pale ones—many of the latter being remarkably metallic. He showed further that the period of greatest susceptibility is when the caterpillar rests motionless upon the surface from which it will subsequently hang as a pupa. The utility of metallic spots on the chrysalides of butterflies is not at first very obvious; but Professor Poulton points out that these would harmonise with recently fractured rock-surfaces which presented such glittering minerals as mica; and that the caterpillars of the small tortoiseshell butterfly, as well as certain of its allies, commonly leave their food-plants and resort to mineral surroundings before assuming the pupa state. "In England" (he writes) "we very rarely see a brightly metallic pupa, because in our moist climate exposed rock-surfaces quickly weather and become lichen-covered. If, however, the bright appearance of many recently fractured rocks were retained, as they are in drier countries, they would cause the production of a similar appearance in the pupæ of those larvæ which sought them."

Owing to the increase of vegetable life, and the consequent covering up of mineral surfaces, there is reason for believing that species with metallic chrysalides are gradually adapting themselves to the changed conditions. In the case of the peacock butterfly (*Vanessa io*) "there is a dark variety which is formed when pupation takes place upon dark rock-surfaces; but the golden form has been replaced by a green variety, which is produced when the chrysalis is suspended from the leaves of its food-plant. The green variety still retains the metallic appearance, and exhibits it to a much greater extent than the dark variety." Professor Poulton found that the green variety of this chrysalis could also be produced artificially by means of a gilt or a white environment. With regard

to the red admiral butterfly (*Pyrameis atalanta*), which has a dark and a glittering variety of the chrysalis, but no green form, he writes: "I have shown that this species is also susceptible, and that either variety of pupa is produced by the appropriate environment. But this chrysalis is very commonly found attached to the food-plant, and when this is the case it hangs suspended in a tent formed of leaves carefully spun together by the caterpillar, so that it is concealed from view. The larva also often has the habit of partially biting through the leaf-stalk or stem, so that the leaves of its retreat hang down and wither. The dead brown leaves thus afford a far more harmonious background for the dark pupa, if by any chance it becomes exposed to view."

So far as is known, no adult insect, in its own lifetime, is able to adapt its colours to a particular environment; nor is this surprising when we remember that, in the perfect state, the integuments usually become hard and lifeless. Nevertheless, through the agency of natural selection, different races of the same species undoubtedly acquire a coloration appropriate to the localities which they frequent. Thus Professor Poulton "observed that a very abundant grasshopper was invariably reddish-brown, like the earth, upon the island of Heligoland, but that the same species was always sand-coloured or green on the flat, sandy Düne, separated by three-quarters of a mile of sea." It is also noteworthy that the colouring of many insects, especially Lepidoptera, tends to become darker as the range of the species recedes from tropical or sub-tropical regions. This is probably due to the greater sombreness of vegetation—especially the prevalence of dark tree trunks and undergrowth—in northern countries. Moreover, there is reason for thinking that the smoke of our great manufacturing areas, by blackening the tree

trunks and destroying bark-infesting lichens and algæ, has called into being distinct races of dark-winged moths such as are seldom or never seen in other districts.

Over and above these settled adaptations to a particular environment, we find that certain insects which pass through two or three generations in the year undergo seasonal changes—*i.e.* the early and late broods of the same species differ in colour and marking. This phenomenon, which is known as seasonal dimorphism, may be seen in our own white butterflies—individuals of the spring brood being more deeply marked than their descendants of the succeeding summer brood; while in certain exotic species the difference between the wet- and dry-season forms is sometimes so remarkable that the insects were formerly regarded as distinct species. Professor Poulton tells us that "in northern latitudes the differences between the early and late broods of the same species sometimes correspond to differences in the surroundings, and thus promote concealment. In tropical countries the dry-season forms are often better concealed than those of the wet season, when the struggle for existence is less severe." It must be admitted, however, that the significance of these seasonal changes is by no means fully understood. In some cases the application of artificial cold suffices to produce spring forms from summer pupæ, while more rarely the summer form is obtained from winter pupæ which have been kept in a hot-house. From this it appears that the atmospheric environment of the pupa may directly influence the colours of the perfect insect.

Before concluding this chapter, reference must be made to the manner in which certain insects conceal themselves by carrying about odds and ends of the substances among which they live. The most familiar

examples are the caddis-worms, which construct portable dwellings of small stones, leaves, twigs, fragments of rushes, or the shells of aquatic molluscs. In these they pass the larval and pupal stages of their existence, vacating them only when they quit the water to assume the adult state. Similarly, the larvæ of some clothes moths make cases, using fragments of the cloth upon which they feed; while in the family *Psychidæ* the caterpillars employ leaves, grasses, or pieces of heather for the same purpose.

Many caterpillars spin leaves together in order to provide a shelter for the critical pupal period, and this habit probably gave rise to the cocoon-making instinct which is highly developed in certain families. Normally the cocoon consists of silk, and it has been proved that at least some species—*e.g.* the emperor moth (*Saturnia pavonia*)—can adjust the colours of their cocoons, making them either light or dark in accordance with the environment. Other species work foreign objects in their cocoon, such as leaves, moss, or pieces of twig, thereby strengthening it and rendering it less conspicuous. The cocoons of the "puss" and "kitten" moths (genus *Cerura*) are formed from fragments of bark mixed with silk acted on by formic acid. They are extremely difficult to discover, as they are exactly like natural flaws or excrescences of the bark itself. It should be noted that the silk glands of caterpillars, caddis-worms and Hymenopterous larvæ are thought to be homologous with the true salivary glands. They open in the region of the mouth; whereas those of certain Neuropterous, Coleopterous and Dipterous larvæ (also spiders) have their place at the posterior end of the abdomen. Silk is a fluid secretion which hardens rapidly when exposed to the air.

CHAPTER IX

WARNING COLOURS AND MIMICRY

We have seen that vast numbers of insects are protected from hostile attack by a close resemblance to their habitual surroundings, and that this resemblance is due mainly to colour adjustment. But the veriest tyro in nature study must have noticed that many insects are not disguised in this way. On the contrary, their colours are crude in tone and boldly contrasted. This is the case with the common wasp (*Vespa vulgaris*), the ladybird beetle (*Coccinella*), and the caterpillar of the cinnabar moth (*Euchelia jacobææ*)—to cite only three well-known examples. Such insects seem to court attention. Clearly they are not coloured to be hidden, but in order that they may readily be seen. How are we to account for this? There is reason to think that such showily coloured insects almost always possess some offensive or hurtful character which renders them unpalatable, and that their showy liveries act as warning advertisements to insect-eating animals. All insects are relatively frail creatures. The hard armour of a beetle avails little against the beak of a hawk or the teeth of a monkey, while one peck from a bird bent upon testing the edibility of a moth or caterpillar is likely to prove fatal. Thus the mere fact that an insect is unsuitable for food will not suffice to save it from destruction. But if a noxious or unpalatable insect is coloured in a manner so striking that its appearance becomes firmly fixed in the mind of its assailant, a distinct advantage to the *species* is likely to result. For the

assailant, profiting by experience, will refrain in future from attacking similarly coloured insects. We shall readily admit, for example, that an animal which has once suffered from the sting of a wasp is likely to recognise and avoid wasps for the rest of its life; while the same reasoning applies to insects, such as the ladybird and the cinnabar moth caterpillar, which have a nauseous taste. The whole conception is based upon the truth of the adage, "once bit twice shy." Obviously a considerable number of conspicuous insects must fall victims each year to the attacks of young and inexperienced assailants. But in nature the welfare of the individual is always subordinate to that of the species; and it is clear that "protected" species—as those which possess some noxious quality are usually termed—cannot fail to reap advantage if their appearance is such that they will readily be seen and recognised.

This theory of warning coloration was first suggested by Dr. A. R. Wallace to account for the extremely bright colours displayed by certain caterpillars. It has since been applied to whole groups of insects, of all orders; and so strong is the evidence in its favour—the result of systematic experiments conducted in various latitudes with birds, reptiles, and other insectivorous creatures—that what was once hypothetical may now be regarded as a well-established fact. Indeed, so characteristic are the colours and patterns of protected insects, as distinct from those which possess no noxious qualities, that an expert naturalist is often able to form a shrewd guess as to whether a newly discovered insect is warningly coloured or not, even though he may be quite ignorant as to its habits. Black, associated with white, yellow, or red, are the commonest warning combinations; while the patterns usually consist of strongly defined rings, stripes, or spots.

Alternate rings of black and red or yellow are the common liveries of stinging insects in all parts of the world—witness the wasps, hornets, and humble-bees. Certain caterpillars, such as those of the cinnabar and buff-tip moths, are similarly coloured; while others display showy stripes or spots. Many of these conspicuous caterpillars have been proved experimentally to be objectionable to most insectivorous creatures, either on account of their unpleasant taste, or because they are covered with irritating hairs or spines. Thus, the caterpillar of the buff-tip moth (*Phalera bucephala*), being tough and unpalatable, is much disliked by birds. That of the well-known vapourer moth (*Orgyia antiqua*) was offered by Dr. F. E. Beddard to a green lizard, "which seized it, and seemed at the same time both anxious and unwilling to eat it. The lizard appeared to intimate that it would eat the caterpillar if it were not for its hairy covering." Vapourer moth caterpillars feed upon a large variety of plants and trees, and several years ago they became a perfect plague in London parks and gardens, notwithstanding the ubiquity of the London sparrow, which feeds freely upon smooth green and brown caterpillars.

Warning coloration has probably reached its zenith among four great sub-families of tropical butterflies—the *Danainæ*, the *Acræinæ*, the *Heliconiinæ*, and the *Ithomiinæ*. These butterflies, of which many hundreds of species are known, are without exception strikingly coloured, and are rendered unattractive as food by the evil-smelling juices of their bodies. Moreover, it is noteworthy that they usually display the same colours on both the upper and under surface of their wings; whereas those kinds that are not protected by distasteful qualities generally have the under surface of the wings coloured to harmonise with leaves, bark, or the surface of the soil—even though

the upper surface may exhibit attractive tints. Again, warningly coloured butterflies are leisurely in their flight. They flutter in an unconcerned manner along the forest glades, or from flower to flower, as though experience had freed them from that instinctive dread of hostile attack which is common to most animals. Nor is this confidence misplaced. When in Nicaragua, the naturalist Belt became convinced that birds, dragon-flies, and lizards avoid the Heliconine butterflies, because their wings were not found lying about in places where insectivorous creatures were accustomed to feed; whereas wings of the edible forms were so found. He also relates that a pet white-faced monkey always refused to eat Heliconine butterflies when these were offered to it. Similar facts have been recorded by competent observers anent the protected butterflies of Africa and the Indian region.

Clearly the weight of evidence goes to prove the usefulness of warning colours to those insects which display them. Yet we cannot claim that conspicuous colours imply complete immunity from molestation. It has already been shown that many protected insects must necessarily fall victims to inexperienced assailants. But apart from this, observers have generally found that a warningly coloured insect which is avoided by some, perhaps by most, insectivorous animals, is readily eaten by one or a few kinds. It has also been proved by experiment that a hungry animal will often eat an insect which would otherwise be refused. Again, certain kinds of birds, such as cuckoos, feed largely and by preference upon hairy and spiny caterpillars. It is clear, therefore, that noxious qualities and their associated colour signals are of little or no protection against some enemies; nor is this a matter for wonder. "No kind of protection," says Professor Carpenter, "can avail at all times and in all

cases. The struggle for life among insect-eating animals must lead some to acquire the power to feed upon kinds which others cannot touch. And the fact that brilliantly hued insects at times fall victims to hungry birds, lizards, or monkeys, cannot destroy the experimental evidence that bright colours are commonly associated with hurtful or nasty qualities."

Probably the strongest testimony to the value of warning coloration in Nature is afforded by the likeness which many harmless insects bear to others that are harmful or disagreeable. Such cases are usually referred to as "mimicry," although the word is sometimes employed to describe deceptive appearances which should really be spoken of as protective resemblance. This confusion should be avoided. True mimicry, as interpreted by science, consists in the external likeness of a poorly protected animal (the mimic) to a well protected one (the model), whereby the former is enabled to share in the immunity from attack enjoyed by the latter. Thus, we ought not to say that a butterfly mimics a leaf, or that a stick is mimicked by a caterpillar.

Let us examine an actual instance of mimicry among British insects. The poplar clearwing moth (*Trochilium apiformis*) is very unlike a typical moth. Its wings are transparent, tinged with yellow; its thorax is brown, with a square patch of bright yellow on each side; its abdomen is yellow, with a brown belt near the base, and another near the middle; while its legs are deep orange. It has, moreover, a general air of trim alertness that is very unusual among scale-winged insects. But although the poplar clearwing is unlike a moth, it is very much like a hornet (*Vespa crabro*). Indeed, it is doubtful whether a casual observer could distinguish between the two insects merely by ocular examination. Yet we know that a

hornet and a moth belong to widely distinct orders, and have nothing whatever in common. What, therefore, can be the meaning of the close superficial likeness which exists between them? At one time naturalists were quite unable to answer this question. To-day, in the theory of mimicry, we find a plausible explanation. Like the wasp, the hornet is a protected species. Everyone knows that it is capable of inflicting painful and even dangerous wounds with its poison-injecting sting; and as a warning to its would-be assailants it displays a livery of yellow and dark brown. Now it is not difficult to believe that a perfectly harmless insect which happens to look like a hornet may actually be mistaken for a hornet; and in the case of the poplar clearwing there is little doubt that this really occurs. The moth shares in the evil reputation of its model, being passed over as dangerous by insectivorous creatures which would gladly eat it did they realise the true state of affairs. We must not think, however, that any conscious imitation is implied when one insect is said to mimic another. No amount of effort on the part of a moth would suffice to alter its appearance in the least degree. But just as natural selection has clothed one set of insects with warning liveries, so the same agency has turned out another set of elaborate frauds.

Bees, wasps, and their kindred furnish models for mimicry in all parts of the world. The males of the various stinging species are really mimics of their own wives and daughters, for they have no stings, and their warning liveries are thus lacking in direct significance. Then there is a whole group of clear-winged moths which look like hornets, wasps, and humble-bees. Many two-winged flies also counterfeit these stinging insects. There is one called *Chrysotoxus silvarum* which looks exactly like a wasp. Another species, known as *Volucella bom-*

bylans, appears regularly each year in two forms, one black and red, the other black and yellow, each form bearing a close resemblance to a distinct species of humble-bee. Again, the familiar bee-flies (*Bombylius*) are veritable "doubles" of small brown humble-bees, while the so-called drone-fly (*Eristalis tenax*) is a creditable replica of the hive-bee. All these examples of mimicry, and many others, may be observed within the confines of the British Islands. The case of the drone-fly and the hive-bee is in some ways unique, because the latter is among the very few protected insects that are not strikingly coloured. We must not forget, however, that the hive-bee is supremely successful and self-assertive, while its sting is even more deadly than the wasp's. Thus, it is not surprising that the bee is recognised and avoided, its sober livery notwithstanding, or that it has become a model for mimicry. Professor Lloyd Morgan found that young birds, having tasted worker hive-bees and rejected them with disgust, subsequently refused to touch not only drones, which have no stings, but also the mimetic drone-flies.

Bees and wasps are also mimicked by beetles. A curious species called *Emus hirtus*, which is allied to the familiar "devil's coach-horse," is thickly clothed with long, yellowish hairs, and looks exactly like a humble-bee when on the wing. Like its model, it loves to fly in the hot sunshine, instead of skulking under stones and refuse after the manner of its kith and kin. This beetle is very rare in England, though common on the Continent; but we have our own wasp beetle (*Clytus arietis*) which is very abundant in flowers during the early summer. It is a member of the great "long-horn" family (*Cerambycidæ*), and some of its tropical cousins are among the most remarkable mimics known. Like the clear-wing moths,

they counterfeit various wasps and hornets, often with marvellous fidelity. Their elytra, or wing-cases, are so much shortened as to be quite inconspicuous—a character very rare in the group to which these insects belong. In this way the functional wings, whether in use or folded above the abdomen, are always fully exposed to view, just as they are in the case of a wasp or a hornet. Of course the beetle has only two flying wings, whereas Hymenopterous insects always have four; but this is a detail which does not strike the casual observer, because the beetle's wings are proportionately broad, with lobed portions in the hind margins which suggest the presence of a second pair.

Dr. G. B. Longstaff, in his recently published work, *Butterfly Hunting in Many Lands*, has the following interesting note respecting one of these beetles which he captured near Sydney in 1910. "On the flower of a shrubby acacia, well within reach and clear sight, was, as I thought, a fine wasp. It was easily netted, but not so easily bottled. I pursued it up and down the net with the cyanide-bottle, taking great care not to be stung. Once corked up I thought no more about it, until on turning out the bottle after the day's work I found a black and orange Longicorn beetle!"

Not a few dominant, well-protected beetles are mimicked by their weaker kindred, or by insects of other orders. Thus, tiger-beetles are avoided on account of their ferocity, and are mimicked by certain inoffensive beetles; while in the Philippine Islands a harmless cricket so exactly resembles a tiger-beetle from the same locality that even experienced naturalists have been deceived by the likeness. Again, the appearance of hardness is possessed by certain beetles which, in reality, are not hard at all. This is doubtless due to the fact that other beetles

with which they associate rely for protection upon the unusual hardness of their integuments. They are probably perfectly edible; but the smaller insectivorous birds are unable to feed upon them because they cannot pierce their armour. Some hard beetles and their mimics are almost identical in appearance; yet the one specimen would need a smart blow from a hammer to destroy it, while the other might be crushed between the finger and thumb. We see, therefore, that the association of inedible qualities with warning colours does not constitute the only model for mimicry. Sometimes a distinctive characteristic is copied, or a striking habit. For example, leaf-cutting ants are common in certain parts of tropical South America. They may be seen in countless numbers passing to and fro along their runs; and each homeward-bound ant carries a piece of green leaf, about the size of a sixpence, in its jaw. Not only the appearance of the ant itself, but also the semblance of the piece of leaf, are reproduced in the person of an inoffensive plant-bug; and there seems no room for doubt that this insect shares in the immunity from attack enjoyed by the leaf-cutting ants, which are avoided because of their fierce, warlike nature.

The most striking examples of insect mimicry are found among tropical Lepidoptera. When the naturalist Bates returned from his travels in South America he brought with him a large collection of butterflies, among which were some that he had placed together, believing them to be of the same species. Closer inspection revealed the astonishing fact that the supposed identity was only superficial; that species belonging to distinct families were so much alike in shape, colour, and markings as to be absolutely indistinguishable when on the wing. The full significance of this discovery cannot be grasped by

those who share the popular belief that one butterfly is very much the same as any other butterfly. Many thousands of distinct butterfly forms exist, and these fall naturally into families, each of which is characterised by structural differences as marked as those which separate dogs from horses, or cassowaries from sparrows. We have seen that whole families of butterflies are rendered unfit for food because of the pungent juices which permeate their tissues. Other groups, such as that to which our common white butterflies belong, comprise species which are perfectly edible and much sought after by insectivorous creatures.

Plate XXIII represents some South American butterflies. The species called *Dismorphia praxinoë*, of which both sexes are shown, is the mimic. Why there are two models will be explained subsequently. For the moment we will focus our attention upon the female *Dismorphia*. A casual observer, misled by colour and shape, would probably fall into Bates's initial error and class the insect along with its models. But a detailed examination brings to light certain racial traits—more especially the arrangement of the nervures, or "veins," of the wings and the development of the legs—which inform the systematic naturalist that the species belongs to the family of typically black-and-white butterflies called the *Pieridæ;* while in the case of the male, a remnant of this early character—the whiteness of the wing—is actually retained on that part of the hind-wing which is not seen during flight. It is to this family that our "cabbage whites" belong, while many of its South American representatives differ little from their kindred of the Eastern Hemisphere. Others, like *Dismorphia praxinoë*, exhibit a wonderful mimetic likeness to distasteful types with which they have no real affinity.

We may well ask by what process this insect has come

to differ so strikingly in colour and shape from the typical members of its family. At first thought we may fail to find in natural selection an adequate explanation of a case so remarkable. But we must remember that we are looking at the latest result of a work which may have been in progress for many thousands of centuries. In the beginning, both the models and the mimic were probably much more simple in colouring than they are to-day. Then, as the models became more elaborate, the mimic followed suit, diverging gradually under the guidance of natural selection from the typical members of its family. Nor is it possible to dogmatise as to the degree of variation upon which natural selection works most fruitfully. We know that every offspring of a given insect differs in minute details from its parents, yet we need not infer that these slight differences afford the only openings for profitable selection. From time to time varieties arise that are glaringly unlike the ancestral type. Great and sudden jumps, as it were, are taken by Nature. Moreover, it is noticeable that certain species are especially liable to vary in this extreme degree, and that the same kinds of varieties (mutations as they are called) are produced over and over again. In all such cases interbreeding among similar varieties must occur; and some naturalists (who follow Professor De Vries of Amsterdam) assert that all species pass through these periods of instability in the course of their history—periods when swarms of incipient species arise suddenly from the old stock. On this assumption the profound modification of an existing species, or the making of new ones, might be a comparatively rapid process; for while many of the mutations are destined to fall before the ordeal of natural selection, a few may pass muster and transmit their distinctive characters to posterity.

PLATE XXIII

Convergent Mimicry: The figures (from above downward) represent *Melinæa imitata* (sub-family *Ithomiinæ*), *Heliconius telchinia* (sub-family *Heliconiinæ*), *Dismorphia praxinoë*, female and male (family *Pieridæ*). South America

The case of *Dismorphia praxinoë* is by no means isolated. Examples of mimicry among butterflies are now known by hundreds, not only in South America, but in all the warmer regions of the globe. In some instances as many as a dozen weaklings, including day-flying moths, are attached mimetically to a single dominant distasteful type. Yet we must not assume that the mere fact of one insect's resemblance to another necessarily constitutes a case of mimicry. Uniformity of habit and environment may, on occasion, lead to uniformity of appearance. There are instances on record of insects indigenous to countries extremely remote which might well be put forward as examples of mimicry if a likeness in form and colour were the only test. Even when two similarly coloured insects are found in the same country, the mere fact of a mutual resemblance proves nothing. We have in England two totally distinct moths known as the marvel-du-jour (*Agriopis aprilina*) and the scarce marvel-du-jour (*Dipthera orion*). The former is common, the latter comparatively rare, as its popular name implies. In each the fore-wings are beautifully mottled with green, interspersed with black and white markings, while the hind-wings are smoky-grey. A hastily formed judgment might lead us to conclude that one insect is mimicked by the other; but the fallacy of such a notion is evident when we learn that whereas the scarce marvel-du-jour flies in June, the common marvel-du-jour does not appear until October. Both moths, however, rest during the day upon tree trunks, and in this position they resemble the same kind of green lichen. Thus the similarity of the two species is clearly due to their likeness to a common object. To establish a case of mimicry it is necessary to show in the first place that one of the insects, the model, really possesses some hurtful or nauseating quality that renders

it distasteful to the majority of its enemies, and in the second place that the habits of the supposed mimic are such as will enable it to share the model's immunity.

Not infrequently the sexes of a butterfly differ so remarkably in colour and pattern that the casual observer would certainly mistake them for distinct species; and when this is the case with a distasteful butterfly that has become a model for mimicry, the respective types of colouring are sometimes reproduced with the utmost fidelity by the males and females of the mimic. There are other instances in which only the female of a species is mimetic, the male retaining the normal colours of its ancestry; while a single species may have two or more distinct forms of female, each coloured in imitation of a separate evil-tasting model. This is explicable on the grounds that the females are comparatively slow in flight, and are exposed to dangers from which the males are exempt—as when they are engaged in egg-laying; while when there are several forms of female to a given species, each mimicking a different model, we have a clear case of divided risks, the advantages of which are too obvious to call for emphasis. One of the most interesting instances of this kind is shown on Plate XXIV. The butterfly (*Hypolimnas misippus*) is not distantly related to our purple emperor. Its headquarters are in India, but it has a wide range in the Eastern Hemisphere. The common form of the female is bright tawny, edged with black, with a conspicuous band of white in each fore-wing. It is a wonderfully exact copy of a much-mimicked Danaine butterfly called *Limnas chrysippus*—perhaps the most dominant of all Eastern insects—which is common all over Southern Asia and Africa. There are numerous closely allied forms, whether constant local varieties or actual species is not definitely known. Now the geogra-

PLATE XXIV

Mimicry: *Hypolimnas misippus*, male (upper figure) and (to left) three females of the same species. To the right, the three warningly coloured models of the genus *Limnas*. Eastern Hemisphere

phical range of *H. misippus* is very similar to that of the Danaine butterflies, and wherever a change of coloration occurs in the latter, it is invariably reproduced by the mimicking females of the former. The three chief forms of the model and its mimic are shown, but there are numerous intermediate varieties. Nevertheless, while the females invariably follow the lead set by the distasteful model in different localities, the colouring of the male is always the same. It is interesting to note that Mr. Frank Finn, when in India, proved by experiment that *H. misippus* is liked by birds which will not touch the malodorous *Limnas*.

In the case of *H. misippus* Nature has obliterated every trace of the manner in which she achieved this triumph of deception. No intermediate stages remain to connect the mimetic colouring of the females with the ancestral colouring of the males. But a closely allied butterfly, called *H. bolina*, supplies a kind of key to the mystery. This insect is not found in Africa, but it is common in the Indian region, where it exists side by side with *H. misippus*. The males of the two species are practically identical in coloration, but the females of *H. bolina* vary in a most erratic manner. Some are almost like their mates, others look like half-finished copies of common evil-tasting types, while the majority are barefaced "sports." Many of them, however, are exceptionally interesting to the student of evolution because they show a gradual increase of tawny colouring from a small spot to a large suffusion of the wing-area. Such specimens go far to bridge over the gap which exists between the black-and-white males of *H. misippus* and their mimetic, tawny females. They do not, indeed, supply us with a full and complete solution of the evolutionary problem which is involved; but such a series of

connected variations show that it is at least possible for very elaborate colour specialisations to arise, in process of time, from very small beginnings—as Darwin pointed out many years ago in regard to the feathers of the peacock. Variableness is, as it were, the motive force behind the evolution of all living things; and it is only as this force is restrained, harnessed, driven along a definite course by the law of natural selection that evolution becomes possible. It is easy, therefore, to imagine how those females of *H. misippus* which originally approached most nearly to the warningly coloured models were benefited in the struggle for existence, and how in the end they became firmly established to the exclusion of all other forms; while in the case of *H. bolina* we are free to believe that an identical process of selection is even now in progress.

Equally interesting is the case of certain swallow-tail butterflies which are confined to Africa and Madagascar. They are usually spoken of collectively as *Papilio dardanus*, though there are many local forms, or sub-species, each of which has been accommodated with a name. The males have always angular, sulphur-yellow wings, marked with black, while each hind-wing ends in a long tail. The females, however, usually have rounded wings, without tails, while their colours resemble those of various distasteful butterflies which abound in the same localities. This is the rule. But the Madagascan representatives of these butterflies, and one or two East African forms, have black-and-yellow tailed females which are almost identical with their males in shape, colour, and pattern. Why have these isolated races failed to participate in the scheme of mimicry from which their congeners presumably derive benefit? The question is not easy to answer. Yet in the absence of contradictory evidence we may assume that

these non-mimetic races have suffered less hardship and persecution than those which have gained the protection of mimicry. In the case of the Madagascan race this view is certainly plausible, and is adopted by Professor Poulton. "It requires a very slight exercise of the imagination," he writes, "to picture the steps by which these marvellous changes have been produced; for here the new forms have arisen at so recent a date that many of the intermediate stages can still be seen, while the parent form has been preserved unchanged in a friendly land, where the keen struggle of continental areas is unknown."

Let us now turn once more to Plate XXIII. The two distasteful models which are mimicked by the *Dismorphia* are practically identical in appearance, yet they belong to distinct sub-families. We see, therefore, that in addition to the mimcry of protected species by harmless ones, there is a mimicry within the protected groups themselves. Cases of this kind were remarked upon by Bates, but he did not explain them. It remained for the late Dr. Fritz Müller, a German naturalist resident in Brazil, to show that if warning colours and mimetic resemblance are really beneficial to insects, no limit can be set to the sphere of their usefulness. He proved that it must be advantageous for protected species to resemble each other for the reason that these species are never absolutely exempt from hostile attack. The usefulness of warning coloration depends upon the fact, established by numberless experiments, that young insectivorous creatures do not *inherit* a knowledge of what they may eat with impunity, and what they ought to avoid; they have to learn by actual tests as they grow from youth to maturity; and this means that a certain number of victims must be drawn each season from the ranks of every protected species, no matter how glaringly conspicuous its warning

livery may be. But it is clear that if several uneatable species resemble one another so closely that they are practically indistinguishable, the relative loss sustained by each as a result of "experimental tasting" will be greatly lessened. Supposing the species to be equally numerous in individuals, the whole matter is reducible to a simple calculation in arithmetic, subject, of course, to the law of average. Thus, if two similarly coloured species are concerned, the loss sustained by each will be halved; if four are concerned, it will be quartered; and so on. Moreover, when two species unequal in numerical importance are involved, the rarer of the two has the advantage. Dr. Müller's demonstration of this was essentially as follows: Suppose that the birds of a region have to destroy 1200 butterflies of a distasteful species before it becomes recognised as such, and that there exist in this region 2000 individuals of species A and 10,000 of species B; then, if they are *different* in appearance, each will lose 1200 individuals; but if they are deceptively alike, this loss will be divided among them in proportion to their numbers, and A will lose 200 and B 1000. A accordingly saves 1000, or 50 per cent. of the total number of individuals of the species; and B saves only 200, or 2 per cent. Thus, while the relative numbers of the two species are as 1 to 5, the relative advantage from their resemblance is as 25 to 1. In view of these facts it is clearly advantageous for numbers of different species to resemble one another closely—to converge, as it were, upon a single type; and this is why we find a general similarity in colour and pattern among great groups of species in all parts of the world. The experience gained by a young insectivorous creature at the expense of one species holds good for another species that resembles it superficially, and so on throughout the whole range of similarly coloured species, dis-

tasteful and palatable alike. In this way true or Batesian mimicry, and convergent or Müllerian mimicry, merge into one great law. Moreover, the principle is not merely one of line-for-line imitation, nor is it limited to insects of one order. "From groups of species within the same order," writes Professor Raphael Meldola, "such as butterflies and moths, groups of different genera of wasps or beetles, and so forth, we can gather a more widely abstract idea of types of warning colours common to whole tribes of insects, irrespective of the orders to which they belong. In other words, we can discern over and above the actual mimetic resemblance, which may be more or less exact, a kind of general similarity in design which suggests that certain *types of pattern* have been fixed by the action of natural selection as outward and visible signs of distastefulness. Thus, the yellow and black-banded pattern so frequently observed in wasps, flies, beetles, &c., is a very good example of a common warning type of pattern . . . it is only necessary to add that from the insects inhabiting one district it is often possible to detect similar arrangements of colour and marking among beetles of various families, flies, wasps, and bees, bugs and moths—a most heterogeneous assemblage of orders, none of the species being exact mimics of each other in the strictly Batesian or Müllerian sense, and yet all presenting a general uniformity of colouring and pattern."

CHAPTER X

THE PROBLEM OF DEFENCE

In the two preceding chapters we have seen that very many insects derive protection from what is really an elaborate system of fraud. Their identity is hidden, so to speak, behind a mask, and they are thus passed over or avoided by their enemies. But this principle can only be regarded as a first line of defence, which avails just as long as the deception is maintained. For no matter how perfect a resemblance may be, it is always liable to be discovered; and when this happens, the insect must be able to adopt active measures for defence, or its chance of life is small indeed.

Certain insects have been observed to assume startling attitudes under the stimulus of alarm, thus scaring away their assailants. A good example is the caterpillar of the lobster moth (*Stauropus fagi*). Ordinarily, it has the appearance of a withered and crumpled leaf; but when disturbed, it immediately assumes what has been called its "terrifying attitude." In this position it looks like a large spider, but with all the characteristic points of a spider's anatomy greatly exaggerated for the sake of effect. Experiments have shown that this strange defensive habit is of no little avail against the attacks of birds and other insectivorous creatures, which exhibit varying degrees of alarm and disgust at the sudden transformation. Moreover, it has been suggested that the spider-like appearance may be especially useful as a safeguard against the attacks of ichneumons. A large and presumably ferocious spider

Caterpillar of Lobster Moth (*Stauropus fagi*)

Caterpillar of Large Elephant Hawk-moth (*Chœrocampa elpenor*) in its "terrifying attitude"

is a vision of dread to all the lesser denizens of the insect world; so that the caterpillar's terrifying mask probably serves to scare away parasites which are bent upon its destruction. The fact that ichneumons are known to avoid spiders, and are seldom found in their webs, certainly supports this view of the case.

Another remarkable caterpillar is that of the puss-moth (*Cerura vinula*), which, like that of the privet hawk-moth, is difficult to discover among the leaves of its food-plant. When irritated, however, it immediately assumes a most weird pose, and draws back its head into the first body-ring in such a manner that the appearance of a grotesque face is produced—the effect being heightened by two intensely black spots which suggest eyes. This mock face is always presented to the foe, being turned from one side to the other in response to the slightest touch. Further, the caterpillar is provided with a pair of whip-like processes at the posterior end of its body, while it is able to eject an intensely acid fluid from a special gland which opens below the head. All these contrivances, while they undoubtedly serve to ward off the attacks of insectivorous creatures, appear to be chiefly directed against the caterpillar's most deadly enemy—an ichneumon called *Paniscus cephalotes*. This insect attempts to fix its eggs upon the caterpillar's skin, just behind the head; and when it succeeds its victim is doomed. But the caterpillar is at least able to fight for its life by lashing out at its foes with its flagella, or whips, and squirting them with acid.

Other insects appear to trade upon the evil reputation of some well-known noxious creature. Thus, a South American caterpillar mentioned by Bates startled every-one to whom it was shown by its snake-like appearance; while the larvæ of our own elephant hawk-moths (*Chæro-*

campa elpenor and *C. porcellus*) gain protection in a similar way. When quietly resting among the leaves of their food-plant, they are concealed by their brown—more rarely green—colouring. But when alarmed by a rustling of the surrounding herbage, the caterpillar suddenly draws back its head and the first three (or thoracic) segments of its body into those behind. As a result, the front part of its body becomes swollen, and looks like the head of an animal, upon which four enormous, awe-inspiring eyes are prominent. The effect is greatly heightened by the suddenness of the transformation, an inconspicuous creature being changed without warning into the semblance of a grotesque monster. This description applies to the caterpillar of the large elephant hawk-moth. In the case of the smaller species, the posterior pair of eye-spots, though present, is not very conspicuous; so that the caterpillar, in its terrifying attitude, appears to have only two eyes. Professor Poulton tells us that "such caterpillars terrify their enemies by the suggestion of a cobra-like serpent; for the head of a snake is not large, while its eyes are small and not specially conspicuous. The cobra, however, inspires alarm by the large eye-like 'spectacles' upon the dilated hood, and thus offers an appropriate model for the swollen anterior end of the caterpillar with its terrifying markings. It is extremely interesting that the caterpillar should thus mimic a feature which is only deceptive in the snake itself."

A like policy of bluff is adopted by certain adult insects, such as the well-known devil's coach-horse (*Ocypus olens*), which, when alarmed, assumes an attitude of menace, suggestive of a scorpion, although it possesses no sting. But the eye-like spots upon the wings of many butterflies and moths, as well as the so-called "tails" of the hind-wings, are believed to benefit their owners by

diverting attention from vital parts of the body. If a bird, when chasing a butterfly, should strike at and pierce one of these eye-spots, or grab at a tail, the damage done would be slight, while the fugitive would gain time to evade its pursuer. As a matter of fact, naturalists in tropical countries have noticed that many of their captures have their wings torn and punctured in this manner. Moreover, in many of the blue butterflies and hairstreaks the antennæ-like tails of the hind-wings are associated with small eye-spots so as to suggest the appearance of a head at the wrong end of the body when the insect is at rest with closed wings; and this resemblance is enhanced by a constant, slight movement of the hind-wings which causes the apparent antennæ to pass and repass each other in a very life-like manner. That these butterflies often save their real heads at the expense of their false ones seems certain, for the latter are often found to have been injured, or entirely bitten away—presumably by birds, lizards, and other insectivorous creatures.

Many insects illustrate the truth of the adage that discretion is the better part of valour. Thus, some arboreal caterpillars, when alarmed, quickly lower themselves by a silken thread from their leafy home, and hang in mid-air until the threatened danger is past, when they slowly draw themselves up by gathering in the thread with their jaws. Other insects of many kinds "feign death" in the sense that their instincts impel them to drop to the ground, and remain motionless, when stimulated by an unwonted change in their environment, such as a passing shadow. The effectiveness of this habit is often enhanced by the insect's protective resemblance to some inanimate object, as in the case of the raspberry weevil (*Otiorhynchus picipes*), which looks exactly like a small nodule of the soil upon which it lies. The skip-

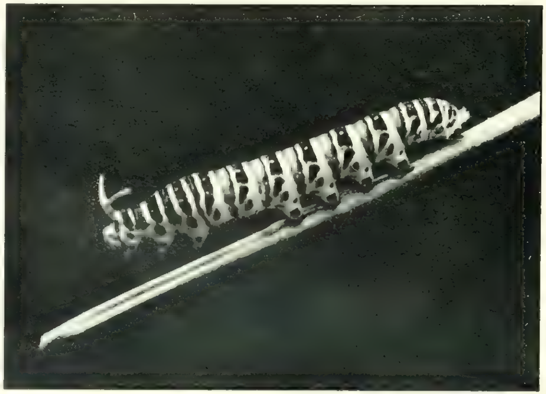
jacks or "click" beetles of the family *Elateridæ*, when surprised and thrown upon their backs, are able to leap high into the air. This feat is rendered possible by a "prosternal process"—a kind of dagger-like projection from the front part of the thorax beneath, which fits into a corresponding groove of the middle thoracic ring. Before jumping, a skipjack arches its body strongly so as to free the dagger-like projection from its groove, and to obtain a purchase for its rapid re-insertion. In this way the tip of the abdomen is made to act as a lever; and when the prosternal process is shot back into its groove with a sharp click, the insect is hurled through the air, and nearly always comes on its legs. It has sometimes been said that the beetle goes through this performance in order to right itself should it chance to fall upon its back; but the fact that it usually "feigns death" when it reaches the ground at the conclusion of a leap suggests that the real object of the manœuvre is to escape from danger. Certain Central American skipjacks have conspicuous eye-like spots upon the upper surface of the thorax; and when, after their sudden jerk through space, they lie motionless with legs and antennæ tucked out of sight beneath the body, they have the appearance of villainous-looking little reptiles—a resemblance which probably serves to scare away their enemies.

Some insects have the power of fighting in retreat. This is the case with the common bombardier beetle (***Brachinus crepitans***), which is preyed upon by larger species of its own family. When one of these gives chase, the bombardier ejects an acid fluid from glands situated at the tip of its abdomen. This effusion immediately vaporises on contact with the air, and looks like a tiny puff of smoke; while at the same time a distinct report is heard, reminding one of a miniature cannon. The dis-

Plate XXVI

Caterpillars of Swallow-tail Butterfly (*Papilio machaon*)

Caterpillar of Privet Hawk-moth (*Sphinx ligustri*) in resting attitude



Caterpillar of Swallow-tail Butterfly, showing Y-shaped tentacle behind the head

A typical Mantid

charge can be repeated several times in rapid succession, though with diminishing force; and as the volatile acid is sufficiently corrosive to stain the human skin a rust-red colour, one can imagine its demoralising effect upon the pursuing enemy. The entomologist Westwood relates that individuals of a large South American *Brachinus*, when seized, "immediately began to play off their artillery, burning and staining the flesh to such a degree that only a few specimens could be captured with the naked hand, leaving a mark which remained for a considerable time."

Some pine-feeding saw-fly larvæ eject a resinous liquid from their mouths when irritated. They are gregarious; and it is a remarkable fact, observed by many naturalists, that if one larva is touched, the whole colony instantly responds by a concerted twitching movement—every individual contributing its quota of the strong-smelling shower. This habit probably helps to defend the larvæ against the attacks of ichneumons. The caterpillars of swallow-tail butterflies are endowed with a retractile, Y-shaped tentacle behind the head. Normally it lies within the body; but it is shot out when the insect is alarmed, and diffuses a penetrating odour, which, in the case of our British species, agrees with that of the food-plant—the hog's fennel or milk parsley. Many other insects emit offensive or noxious secretions, either from the mouth, or from glands situated on different parts of the body; while the blood itself sometimes serves as a repellent fluid, issuing from a pore at the extremity of the femur. This is the case with the ladybirds (*Coccinellidæ*) and the oil beetles (*Meloidæ*). In the latter family, the blood contains cantharidine, an extremely caustic substance, which is an almost perfect protection against birds, reptiles, and predaceous insects. Such

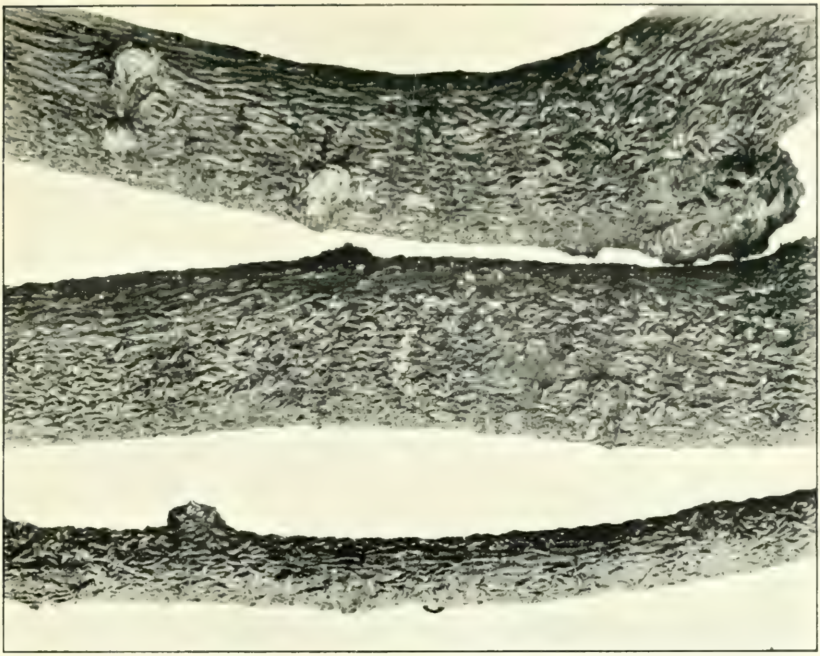
defensive evacuations are commonly associated with warning coloration.

Many insects are protected by the stiff hairs and spines which cover their bodies; while the spines of some caterpillars are hollow and filled with poison. They break to pieces when the insect is handled, and give rise to a stinging sensation like that caused by the hairs of the nettle and other plants. It is said that these stinging hairs defend their possessors from almost all birds except cuckoos.

In the sub-order Homoptera, numerous species find shelter beneath wax-like substances derived from their own bodies. A definite shell, or "scale," is often formed, as in the case of the mussel scale insect (*Mytilaspis pomorum*); or the secretion may be thread-like or downy, as, for instance, in the woolly aphis or American blight (*Schizoneura lanigera*) of our orchards, and the felted beech coccus (*Cryptococcus fagi*). Among the frog-hoppers the young nymph exudes a copious frothy liquid—the familiar "cuckoo spit"—in the midst of which it lies hidden; while the caterpillars of certain saw-flies—known popularly as "slug-worms"—secrete a dark-coloured slime which completely envelops their bodies, and renders them obnoxious to their foes. The larvæ of tortoise beetles (*Cassida*) actually shelter under their own excrement, which accumulates as a kind of flattened scale above the insect's back.

Relatively few insects are endowed with defensive weapons—if we except their mouth-parts, the primary office of which is to procure food. But in certain families of the Hymenoptera, and in these only, we find that remarkable structure, the poison sting. It is an exclusively feminine organ, being a modification of the egg-laying apparatus, or ovipositor, and in many instances still retains

PLATE XXVII



Mussel Scale Insect (*Mytilaspis pomorum*) on stems of Hawthorn

Felted Beech Coccus (*Cryptococcus fagi*) on trunk of Beech

its dual function. But in the unsexed or worker classes of social species it has become a weapon pure and simple. Briefly, the sting of a worker hive-bee consists of a grooved and pointed shaft along which slide a pair of many-barbed darts. Externally, there are two feelers or palpi, which are used to ascertain the most vulnerable point of attack. The first thrust is administered by the shaft, which serves to open a wound and to guide the darts. The latter then strike alternately with a rapid, plunging movement, while the poison is pumped down from a chamber at the base of the shaft. Two glands, one acid and one alkaline, minister to this deadly flow; for while the combined liquid is always acid, an alkaline admixture appears to be necessary to render the poison lethal. It is said that in insects, such as digger-wasps, which merely paralyse their prey, the alkaline glands are functionless or abortive. Moreover, in these insects, and in most other stinging Hymenoptera, the darts of the sting are far less formidably barbed than is the case with the worker hive-bee. Thus, the sting can be readily withdrawn; whereas the bee commonly leaves her weapon sticking in the wound, and suffers a fatal rupture—a remarkable sacrifice of the individual for the benefit of the species. Mr. Cowan tells us, however, that if time is allowed the bee can withdraw her sting by a spiral motion, similar to drawing a cork-screw out of a cork; but she is usually far too agitated to go through this slow performance. The sting of the queen hive-bee is curved, and only slightly barbed, while the contents of her poison-sac differ materially from that of the worker's. We shall see later that this royal weapon is used to despatch rivals when the state of the community does not warrant the sending forth of a swarm.

Many ants are armed with a sting, but in other species, such as the common wood ant (*Formica rufa*), the poison-

sac serves as a reservoir whence formic acid is ejected from an orifice at the tip of the abdomen. To inflict a bodily injury these ants must first bite their enemy, and then squirt poison into the wound ; but when thoroughly alarmed they spray their acid into the air, which soon becomes charged to suffocation with the penetrating fumes. In this way the nests are defended against sudden assault.

The manner in which social insects make war upon their enemies is very remarkable. Each member of the clan seems animated by an unquenchable spirit of patriotism, and concerted movements are carried out with the utmost precision. The temper of the community varies with the species. Wasps are undoubtedly more irascible than bees, and many ants are characterised by a calculating aggressiveness which is especially marked in their slave-hunting propensities. But in general terms it may be said that all social insects are long-suffering, slow to pick a quarrel, with little vindictiveness in their composition. Nevertheless, when once the security of their state has been threatened, they declare war to the knife, as those who have incautiously disturbed a wasps' nest know to their cost. Many species depute sentinels to stand at the threshold of the nest, and thus keep chance pillagers and parasites at bay.

The defensive value of an insect's physical attributes —its armour-like skin, its powers of running, leaping, or flying, and its extraordinary vitality—is too obvious to call for emphasis ; but it is interesting to notice that these endowments are bestowed in exact proportion to the needs of each species. There is nothing incongruous in Nature's scheme. Larvæ which feed in concealment, or are the object of tender solicitude on the part of adult individuals of their kind, are soft-skinned and defenceless ; while

specialised protective devices, whether of form, colour, or habit, tend to detract from mere bodily fitness, except in those cases where the creature's manner of feeding demands alert and dexterous movement. Similarly, the sense-organs and instincts are accurately adjusted to the requirements of each insect in its own sphere of existence. Doubtless there are some supremely successful species, such as the hive-bee and the ant, whose all-round capacity far surpasses the average. But these exceptions are relatively few. Nor is this surprising when we remember how fierce and relentless is the struggle for existence. Moreover, absolute perfection is not desirable, for it would involve annihilation. If an insect were to attain complete immunity from all its enemies, it would, in the course of a few generations, exhaust all possible sources of food, and perish by starvation.

So far we have considered the problem of defence from the standpoint of the individual insect. But this is only one phase of the question, for Nature's chief concern is to save the *species* from destruction. So that we may regard all the wonderful contrivances that enable insects to frustrate the attacks of their enemies as part and parcel of one great scheme for the preservation of the race. Pondering the matter in this light, we realise the far-reaching importance of other factors, such as the insect's tenacity of life, its immense powers of increase, and the surpassing vitality of its eggs. The latter may be subjected to a far greater range of temperature than the animal could survive in any of its three other stages. In what manner this stubborn resistance is contrived we do not know. But it is a fact that eggs laid in the autumn, and not hatched until the following spring, pass unscathed through the severest frosts. Again, the reproductive capacity of many insects is amazing. One instance will

suffice to illustrate this point. A single grey flesh-fly (*Sarcophaga carnaria*) is capable of producing 20,000 larvæ. "Each of these larvæ" (writes Dr. Wallace in *Darwinism*) "remains in the pupa state for about five or six days, so that each parent fly may be increased ten thousand-fold in a fortnight. Supposing they went on increasing at this rate during only three months of summer, there would result one hundred millions of millions of millions for each fly at the commencement of summer —a number greater, probably, than exists at any one time in the whole world." Thus, while the protective devices with which we have dealt can only succeed in a minority of cases, the abounding fecundity of the insect always remains to safeguard the continuance of the race.

CHAPTER XI

CARNIVOROUS INSECTS

Carnivorous insects may be divided into three groups, viz. :—(1) insects of prey; (2) parasites; and (3) carrion feeders or scavengers. By far the larger number of predaceous species assail other insects, but a few feed upon snails, earthworms, and similar small fry, while others practice a kind of intermittent parasitism, and suck the blood of large animals such as cattle and horses. Certain insects attack and devour almost every creature of appropriate size that they happen to encounter. In this category we may include the tiger-beetles, the ground-beetles, and some of the rove-beetles or cock-tails; while the carnivorous water-beetles are equally rapacious in their own sphere of activity, the larger kinds actually destroying young fish on occasion. Dragon-flies display the same indiscriminate ferocity, first in their aquatic larval state, and later when they become denizens of the air. All these insects catch their prey by fair chase—if we except dragon-fly nymphs, which are apt to lurk in seclusion, and dart out their wonderful extensile jaws to seize such small animals as may approach unawares. But other species steal upon their victims, or wait patiently in exposed situations until chance provides them with a meal; and in all these cases the insect cannot fail to reap a double harvest from any resemblance to its surroundings with which it may be vested, for it will be equally well hidden both from its enemies and from its prey.

This principle of aggressive resemblance, as it is called,

is well illustrated by many of the mantids, or "praying insects," all of which are carnivorous. Most of the species are either green or brown in colour; so that when they sit motionless among foliage, or upon the bark of trees, they are well concealed. They have sluggish, indolent habits, and usually adopt a policy of waiting for something to turn up, although at times they steal cautiously from one point of vantage to another, or stalk an insect which has settled beyond their reach. Their wonderful raptorial fore-legs have already been described (p. 63). In the use of these limbs the mantids are amazingly rapid and dexterous, often capturing an insect as it flies past; while the rows of sharp spines with which the modified femur and tibia are armed effectually prevent the victim's escape when once it has been seized.

Although the majority of mantids are either green or brown in accordance with the prevailing tint of their environment, a few species are brightly coloured in such a way that when the insect poses among foliage, the similitude of a flower is produced. Now everyone knows that flowers are attractive to many kinds of insects, which fly to them in order to feast upon nectar or pollen. Bearing this fact in mind, it is not difficult to believe that a flower-like mantid, hanging motionless among green leaves, might easily deceive such insects as bees and butterflies. That these mistakes actually occur is vouched for by more than one competent observer.

Dr. Wallace mentions an insect (*Hymenopus bicornis*), discovered by Mr. Wood-Mason, which attracts other insects to their destruction by its flower-like shape and delicate pink-and-white colouring. Parts of the insect's legs are so flattened as to look like petals. In this instance the whole of the mantid is so contrived that the appearance of an orchid results; but in another species

(*Idolium diabolicum*) from Mozambique the body and walking legs are green, and harmonise with the surrounding foliage, while only the underside of the prothorax and raptorial limbs have a flower-like colouring of purple and white. Moreover, these parts are abnormally flattened and extended; so that what we may call the "business end" of the insect becomes a veritable trap, baited with diabolical ingenuity. Allured by what they take to be a nectar-distilling flower, butterflies and bees fly right into the clutches of the terrible raptorial limbs.

Another flower-mimicking mantid is *Gongylus gongyloides*, from Southern India, an insect which has been known to naturalists for upwards of three centuries, but of whose strange habits nothing was discovered until comparatively recent years. The species is thus described from living examples by Dr. J. Anderson: "On looking at the insects from above they did not exhibit any very striking features beyond the leaf-like expansion of the prothorax and the foliaceous appendages of the limbs, both of which, like the upper surface of the insect, are coloured green, but on turning to the under surface the aspect is entirely different. The leaf-like expansion of the prothorax, instead of being green, is a clear, pale lavender-violet, with a faint pink bloom along the edges of the leaf, so that this position of the insect has the exact appearance of the corolla of a plant, a floral simulation which is perfected by the presence of a dark, blackish-brown spot in the centre, over the prothorax, which mimics the opening to the tube of a corolla. A favourite position of this insect is to hang head downwards among a mass of green foliage, and, when it does so, it generally remains almost motionless, but at intervals evinces a swaying movement as of a flower touched by a gentle breeze; and while in this attitude, with its fore-limbs banded violet

and black, and drawn up in front of the centre of the corolla, the simulation of a papilionaceous flower is complete. The object of the bright colouring of the under surface of the prothoracic expansion is evident, its purpose being to act as a decoy to insects, which, mistaking it for a corolla, fly directly into the expectant, serrated, sabre-like raptorial arms of the simulator."

The nymph of at least one kind of bug (*Reduvius personatus*) has the very curious habit of enveloping itself in a coating of dust and small particles of any refuse among which it may chance to wander. This habit is doubtless protective, but it also serves an aggressive purpose. The *Reduvius* is a cosmopolitan species which frequents the cellars and basements of dirty houses, where it does good service by preying upon other insects—including cockroaches and the objectionable bed-bug. It pierces its victims with its sharp "beak," and extracts their juices exactly as its vegetarian relatives suck the sap of plants.

Many other terrestrial Hemiptera, and most of the aquatic species, are carnivorous. Among the latter are the giant water-bugs of the family *Belostomidæ*. These are abundantly represented in the warm regions of both hemispheres, and some of the species attain a length of nearly five inches. Their grasping fore-legs enable them to hold their prey with great firmness, while their strength is such that they can grapple successfully with such creatures as frogs and small fishes. When full-grown, these bugs have large and powerful wings, so that they are able to leave the water and fly to great distances. Certain North American species have been found in the midst of cities far from ponds, and are known as "electric light bugs" because they are attracted by bright lights on the top of high buildings.

In our own country, the best-known carnivorous water

bugs are the common back-swimmer or water boatman (*Notonecta glauca*) and the water scorpion (*Nepa cinerea*). The latter is one of the commonest British insects. It frequents shallow, stagnant water, and usually lies hidden in the mud; but even when it creeps sluggishly among the weeds, it is rendered inconspicuous by its flattened form and miry guise. Its raptorial fore-legs enable it to play the part of an aquatic mantid by seizing any smaller insect that comes within its reach; but the resemblance ends here, for while the mantid tears its victim in pieces, the water scorpion must needs suck its juices. The water boatman, thanks to its oar-like hind-legs, is a very active insect, and catches its prey by sheer speed and agility. It feeds upon small aquatic creatures, including tadpoles, and is strong enough to master a good-sized minnow. A chance prick from its sucking beak proves to be almost as painful as a bee's sting. Indeed, like many other species, it pours a poisonous saliva into the wound which it makes, thus paralysing or killing its victim.

So far as is known, the curious scorpion-flies, which make up the order Mecoptera, are exclusively predatory, though their caterpillar-like larvæ are believed to feed for the most part upon dead animal matter. The adults, which are especially characteristic of woodland districts, capture other insects. A European species (*Bittacus tipularius*) has unusually long limbs, and resembles a "daddy-longlegs" or crane-fly. It preys upon flies, and when feeding is said to hold its victim with its hind-legs—the other two pairs being used to suspend itself from the stems of grasses.

Many carnivorous insects are very partial in their choice of food; and we find whole groups of families, scattered throughout the orders, which agree in their fidelity to a particular diet. Aphides, for example, are

preyed upon by so many kinds of insects that but for their inexhaustible powers of reproduction their race would assuredly be stamped out. Among their chief enemies are the lace-wing and golden-eye flies of the order Neuroptera. These usually lay their curious stalked eggs in the vicinity of an aphid colony, upon the members of which the active larvæ begin to prey as soon as they are hatched. When full-fed, each larva spins an almost spherical cocoon, which appears remarkably small when compared with its maker, and with the perfect insect which eventually makes its début through a small hole to which the cover remains attached like a lid. By what art this triumph of packing is accomplished remains a mystery.

Two other groups are notably dependent upon aphides for food. These are the ladybird beetles (*Coccinellidæ*) and a section of the hover-flies (*Syrphidæ*). The latter abound in gardens, where the adults frequent flowers and feed upon pollen. The females may often be seen engaged in their task of oviposition. They make sudden darts at buds and stems, and lay their eggs singly among the crowded pests, so that each larva may have a happy hunting ground of its own. When one watches a hover-fly poised before an infested spray, one is tempted to believe that she is engaged in a deliberate calculation as to the number of larvæ its flocks and herds will support. The larvæ, which are not unlike little leeches in appearance, are insatiable in their assaults upon green-fly and other small, soft-bodied insects. Their manner of feeding is peculiar. They rear themselves up on their tails, lash wildly about, and suddenly seize an aphid by means of their hooked mouth-parts. The aphid is then deliberately pulled from its hold upon the plant, and held aloft, where its struggles for liberty are of no avail. It is then rapidly sucked dry;

and when this operation is complete the hover-fly larva casts aside the empty skin and turns its attention to another member of the flock. The importance of these insects from the standpoint of the agriculturist can scarcely be exaggerated. "I have seen currant bushes" (writes Dr. Howard) "upon which there was hardly a leaf which did not support a thriving colony of plant lice and which had not become curled and distorted in consequence; and yet within a few days, while the distortion of the leaves remained, not a plant louse was to be found, but under each leaf instead of the flourishing group of lice was a fat, full-grown syrphus larva which had destroyed all of the previous inhabitants and was now ready to transform."

The well-known ladybirds feed largely upon aphides, though some of them attack such pests as scale insects and red spiders. The most familiar British species are the two-spot ladybird (*Coccinella bipunctata*) and the seven-spot ladybird (*C. septempunctata*). They lay their small, yellowish eggs in groups upon leaves, usually in the neighbourhood of aphid colonies. The dark-coloured larvæ are known popularly as "niggers." They are fairly active in their movements, and never fail to destroy any small, succulent insect which may cross their path. When full-grown, the larva suspends itself by the tail from a leaf, and changes to a pupa.

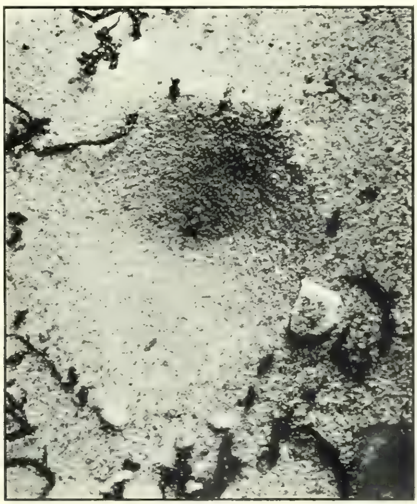
The Neuropterous snake-flies (*Raphidiidæ*) may also be reckoned among the gardener's friends, for their larvæ destroy multitudes of small creatures which lurk beneath the bark of decaying trees, and in like situations; while the adults are rapacious foes of lesser insects in general. According to Dr. Howard, the larvæ of Californian snake-flies are especially destructive to the caterpillars of the dreaded codlin moth, which they attack after they have spun their cocoons under the loose bark of apple trees.

Some years ago an attempt was made to send living Raphidians from California to Australia and New Zealand, where the codlin moth is a great scourge, in the hope that they might become acclimatised and assist fruit growers in their fight with the pest. Unfortunately, the attempt proved a failure.

Relatively few insects set traps for their prey. But this is done by the larvæ of some ant-lion flies (*Myrmeleonidæ*). These insects are not represented in Britain, but the common ant-lion (*Myrmeleon formicarium*) is a well-known European species which has long been studied by naturalists, the first accurate account of its habits having been given by Réaumur. He it was who pointed out the inaptness of applying the name "lion" to a creature which captures its prey by strategy rather than by rapidity and strength. The larva is a strange-looking insect, thick-set and somewhat oval in contour, with a flat head armed with formidable, curved mandibles. It has an ingrained habit of walking backwards, and uses its convex abdomen as a plough. When constructing the pitfall for which it is famous, it usually begins by making a circular groove to correspond with the margin of the proposed excavation. It then ploughs round and round in diminishing circles, constantly jerking out the sand with its shovel-like head. The final result is a funnel-shaped hollow, in the bottom of which the maker lies buried with only its ugly jaws exposed to view. Any small insect which chances to run over the edge of the pit slides downward on the yielding sand, its descent being hastened by the ant-lion, which casts up jets of sand upon its victim. When the latter is seized, further struggles are futile, for the pit-maker's jaws are so constructed that when once buried in the tissues of its prey they need not again be opened. "There is no mouth-orifice of the usual character" (writes

Sexton or Burying Beetles (*Necrophorus*) at work upon the carcase of a Dormouse

Ammophila sabulosa: much magnified



Pit of Ant-lion (*Myrmeleon formicarium*) natural size

Dr. Sharp), "and the contents of the victim are brought into the buccal cavity by means of a groove extending along the under side of each mandible; in this groove the elongate and slender lobe that replaces the maxilla—there being no maxillary palpi—plays backwards and forwards, probably raking or dragging backwards to the buccal cavity at each movement a small quantity of the contents of the impaled victim." After finishing its meal, the ant-lion hurls the empty carcass to a considerable distance from its pit.

Ant-lions require fine, dry sand in order to carry out their operations successfully, and their pits are commonly found in sheltered situations which have a sunny aspect. The duration of the larval life varies greatly, and seems to depend upon the amount of food that is obtained. These insects are able to sustain lengthy fasts, apparently without detriment to their well-being; nor is this surprising when we remember the precarious nature of their livelihood, which depends solely upon chance, for they have no means of luring victims into their pits. But when ants and other food are plentiful, the ant-lion soon attains its full growth, and spins a silken cocoon in the sand. The adult insects are nocturnal and of shy disposition. They are seldom seen even in localities where their larvæ are abundant, and very little is known of their ways, although they are believed to prey upon small winged insects, while they probably lay their eggs in sandy spots such as the larvæ frequent. The habit of making pitfalls appears to be confined to the small genus *Myrmeleon.* In other genera the larvæ walk forward in the normal manner. They either lurk in crannies, or lie half buried in the soil, and rush out upon small insects which may chance to pass their hiding places.

The voracious tiger-beetle larvæ form long, almost

perpendicular burrows in sandy soil, often extending them to a foot or more below the surface. They are whitish, soft-skinned grubs, the head and prothoracic segment being broad and horny. Moreover, the ninth segment is Punch-backed in a remarkable manner, and furnished with two curved hooks, by means of which the larva is able to scramble up or down its burrow, and to support itself just within the entrance, which it blocks up with its broad head and prothorax. In this position it waits patiently until another insect comes within striking distance, when it instantly throws back its head with a rapid jerk and seizes its prey with its strong sickle-shaped mandibles. The victim is then dragged hastily to the bottom of the burrow, and there demolished.

For some reason not easy to fathom, insects have failed to acquire the art, so marvellously perfected in the case of many spiders, of weaving webs for trapping their prey. The only exceptions are found in a family of caddis-flies known as the *Hydropsychides*. Unlike most of their congeners, the larvæ of these insects are carnivorous; instead of constructing portable dwellings, they live in fixed cases made of sand or little pieces of stone fixed together with silk. A Brazilian species, described by Müller, frequents the rapids of rivulets, and makes its home upon the upper surface of a stone. The mouth of the case faces up stream, and is provided with a large, funnel-shaped veranda, over which a beautiful silken net is spun. Several of these larvæ build their funnels side by side on the same stone, like a row of eel-pots, and in this way intercept any small aquatic creatures which may be brought down by the water. The larvæ of an allied North American species have been watched by Dr. Howard, who tells us that in this instance "the tube of the funnel is bent nearly at right angles with the mouth. The mouth

is composed of a network of silk supported by arched bits of twigs. The larva remains hidden in the funnel, watching for its prey to be caught in the open mouth. The cases were preferably placed at the edge of slight depressions in the rocky surface so that the tubular portion was protected from the full force of the current. On the surface of a rock about eighteen inches in diameter 166 of these nets were counted. The larvæ of one of the black flies were very abundant in this stream, and were washed into the mouths of these nets, and probably formed the principal food of the Hydropsyche larvæ."

As might be expected, social insects often engage in concerted raids in search of food. This is notably the case with the South American foraging ants of the genus *Eciton*. They have no fixed abodes, but form temporary resting-places where, presumably, breeding takes place. Little is known, however, of their domestic habits, the identity of their "queens," or egg-laying females, being at present uncertain. The great armies which traverse the forest regions on the banks of the Amazon are made up entirely of sexless individuals, some of which have larger heads and more powerful jaws than others, and are for this reason known as "soldiers." They have no faceted eyes, while some of the forms are quite blind. The habits of the two commonest species of *Eciton* are graphically described by Bates in the following passage: "When the pedestrian falls in with a train of these ants, the first signal given him is a twittering and restless movement of small flocks of plain-coloured birds (ant-thrushes) in the jungle. If this be disregarded until he advances a few steps further, he is sure to fall into trouble, and find himself suddenly attacked by numbers of the ferocious little creatures. They swarm up his legs with incredible rapidity, each one driving its pincer-like jaws

into his skin, and with the purchase thus obtained, doubling in its tail, and stinging with all its might. There is no course left but to run for it. . . . The errand of the vast ant-armies is plunder. . . . Wherever they move, the whole animal world is set in commotion, and every creature tries to get out of their way. But it is especially the various tribes of wingless Arthropods that have cause to fear, such as heavy-bodied spiders, ants of other species, maggots, caterpillars, larvæ of cockroaches and so forth, all of which live under fallen leaves, or in decaying wood. The Ecitons do not mount very high on trees, and therefore the nestlings of birds are not much incommoded by them. The mode of operation of these armies, which I ascertained only after long-continued observation, is as follows. The main column, from four to six deep, moves forward in a given direction, clearing the ground of all animal matter dead or alive, and throwing off here and there a thinner column to forage for a short time on the flanks of the main army, and re-enter it again after their task is accomplished. If some very rich place be encountered anywhere near the line of march, for example, a mass of rotten wood abounding in insect larvæ, a delay takes place, and a very strong force of ants is concentrated upon it. The excited creatures search every cranny and tear in pieces all the large grubs they drag to light. It is curious to see them attack wasps' nests, which are sometimes built on low shrubs. They gnaw away the papery covering to get at the larvæ, pupæ, and newly-hatched wasps, and cut everything to tatters, regardless of the infuriated owners which are flying about them."

The notorious driver ants (*Anomma*) of Africa resemble the foraging ants in their habits, but do most of their hunting at night. Like the Ecitons, they attack every living creature that they encounter, and consume all dead

animal matter. It is said that the dread of them is upon every living thing. Nevertheless, they do good service as scavengers; and when, as is often the case, they visit the dwellings of mankind, they drive forth or destroy vermin of all kinds.

Most wasps, whether solitary or social, are largely predatory; but as their hunting exploits are chiefly enacted for the benefit of their offspring, they will be more fittingly dealt with when we consider the insect in its parental guise. This applies also to ichneumons, and to many two-winged flies, which—themselves free and independent beings—prepare the way for their young to live as parasites. Certain Diptera, however, are predaceous in the adult state, the most notable being the robber-flies (*Asilidæ*) whose larvæ feed inoffensively in damp earth. "These flies" (says Dr. Fitch) "are inhuman murderers. They are savages of the insect world, putting their captives to death with merciless cruelty. Their large eyes, divided into a multitude of facets, probably give them the most acute and accurate vision for espying and seizing their prey; and their long, stout legs, their bearded and bristly heads, their whole aspect indicates them to be of a predatory and ferocious character. Like the hawk, they swoop upon their prey, and grasping it securely between their fore-legs they violently bear it away." Robber-flies pounce upon almost any flying insect that they are strong enough to master, including wasps and bees; nor do they spare their own kind. It is even said that the males are frequently seized and eaten by their more robust mates. Many of the species are endowed with a close mimetic resemblance to stinging insects; and it has been suggested that this likeness may assist them in their murderous enterprises by enabling them to approach their Hymenopterous prey without arousing suspicion. But this theory

of "aggressive mimicry," as it is called, is unsupported by direct evidence; nor is it easy to believe that these swift and agile flies stand in need of any such aid. It is therefore more reasonable to suppose that the mimicry is really protective, serving to exempt the robbers themselves from the attacks of larger insectivorous creatures.

None of the *Asilidæ* has yet acquired the habit of feeding upon warm-blooded animals; but many other Diptera obtain their food in this way, although it is a remarkable fact that (with few exceptions) the females alone are blood-suckers. The males, if they feed at all, are vegetarians; while it is known that many, if not all, of the females are capable of subsisting upon the juices of plants if they are debarred from their favourite food. These considerations suggest that blood-sucking (except among the truly parasitic Diptera) may be a newly acquired habit, due to the enterprise of the so-called gentler sex. These matrons seem to have discovered that the vital fluid of mammals is more easily assimilated, and more sustaining, than the raw sap of plants; and there is reason for thinking that the bad habit may spread in course of time not only to their mates, but to other species which are at present outside the secret.

In a few instances blood-sucking is already indulged in by both sexes. This is the case with the African tse-tse flies, and with three British representatives of the great family *Muscidæ.* Among the latter, the best known is the so-called biting house-fly, or stable-fly (*Stomoxys calcitrans*). It has a close superficial resemblance to its namesake, but it carries a mouthful of lancets, and although it may often be seen imbibing nectar from flowers, it is an inveterate blood-sucker when occasion offers. Like the house-fly, *Stomoxys* breeds preferably in stable refuse. But it is seldom found in houses except just before rain,

when it comes in at open windows—hence the old saying that "flies begin to bite before rain."

Chief among the flies whose females alone are sanguinivorous are the gnats and mosquitoes (*Culicidæ*), and the horse- or gad-flies and their allies (*Tabanidæ*). The grey, green-eyed "cleg," or rain breeze-fly (*Hæmatopota pluvialis*), is probably the commonest British representative of the latter family. During the summer months it is a provoking attendant upon man and beast, especially in woodland districts. The great ox gad-fly (*Tabanus bovinus*)—a robust and handsome insect with a wing-expanse of almost two inches—generally attacks horses, cattle, and deer, which it punishes severely. Of the "stinging" proclivities of mosquitoes and their lesser relatives the midges (*Chironomidæ*) there is no need to write, as everyone has experienced the attentions of these winged nuisances. We have already seen that poisonous secretions are mingled with the saliva of many insects; and this fact accounts for the persistent pain and inflammation which frequently follow a bite. But there is a far more serious aspect of the case, namely, that many insects are known to infect the blood of men and animals with the active elements of disease. We shall recur to this matter when we discuss insects from a purely anthropological standpoint.

Some insects are permanently parasitic, being completely dependent in all their stages upon some other creature. Such are the Mallophaga and the Anoplura (pages 67 and 74); also the spider-flies (*Hippoboscidæ*) and their allies. Certain of the latter are winged, others wingless; but the winged species seem only to make use of their power of flight in order to get from one host to another. The forest-fly (*Hippobosca equina*) is especially abundant in the New Forest, where it may sometimes

be seen clinging in enormous numbers to ponies and cattle. Curiously enough, its bite appears not to cause pain, and beasts which have been bred in the Forest show no signs of annoyance, although strange horses are often driven almost frantic by the irritation caused by the insects crawling over them. All the *Hippoboscidæ* (including the wingless "sheep-tick" or "ked") are viviparous, the females producing at each birth a full-grown larva which immediately changes to the pupal state. The fleas (Siphonaptera), which are nearly related to two-winged flies, are parasites when adult, but their larvæ live an independent life and feed upon the organic matter contained in dust. Perhaps the most completely parasitic of all insects is the female *Stylops*, an outline of whose life-history has already been given (page 83).

Carrion-feeding and scavenger insects are most numerous among the two great orders Coleoptera and Diptera. Enormous numbers of flies habitually resort to filth, or to decaying animal matter, both to feed and to lay their eggs; and their larvæ do good service by rapidly consuming these malodorous substances. No less than 10,282 maggots of the house-fly have been obtained from fifteen pounds weight of manure after only four days exposure, while it is often asserted that a dead horse would be as quickly demolished by the progeny of three flesh-flies as by a lion. The most interesting scavenger insects, however, are found among the beetles. In the course of a summer ramble, one not infrequently comes across a dead animal, such as a bird or a mouse. If the body be turned over with a stick, some of our native sexton or burying beetles (*Necrophorus*) may usually be found busily engaged. Both sexes labour, while several pairs often work in company. They scoop away the soil beneath the carcass, and if it be not too large,

ultimately contrive to bury it. In the end, the females lay their eggs in the carrion, upon which the larvæ are destined to feed. It is recorded that four burying beetles which were kept under observation interred four frogs, three small birds, two fishes, one mole, two grasshoppers, the entrails of a fish, and two pieces of ox liver—all in a period of fifty days.

Besides these true sexton beetles, hundreds of other kinds are attracted to decomposing flesh; while a whole army of species luxuriate in the droppings of animals. One of the latter—the so-called sacred beetle (*Scarabæus sacer*)—is perhaps more famous than any other insect. Its habit of rolling about balls of stercoraceous matter, which it ultimately buries, was formerly thought to be the outcome of parental instinct. Each sphere was believed to contain an egg. But Fabre has watched these insects in Southern France, and has found that in the spring of the year they seek only to gratify their own appetites, postponing maternal cares until the autumn. A scarab having formed its ball, rolls it with much labour to a suitable spot, where it makes a temporary burrow. The ball is then pushed in, the entrance closed, and the beetle settles down to a protracted feast which may continue for a fortnight. When the store of food is entirely exhausted, the insect comes forth to seek fresh provisions, which it treats in a similar manner. One scarab is sometimes joined by another individual which renders assistance in rolling the ball; but when the rightful owner is engaged in excavating the burrow, the false friend is apt to make off with the prize.

In addition to these large scavenger beetles, there are many smaller species which burrow into the soil beneath the droppings of animals, and carry much of the matter into their tunnels. In this way the whole

of a meadow in which cattle have been grazing is rapidly benefited by a fairly even distribution of manure among the roots of the turf.

Although the vast majority of insects are either carnivorous or vegetarian, the gap between the two groups is bridged over by a few species which affect a mixed diet. Some cockroaches may almost be termed omnivorous, for they seem to relish any edible substance that comes their way; and earwigs devour the larvæ of other insects, and small molluscs, as well as fruit and parts of flowers. Social wasps supply their young first with nectar or fruit juice, and later with the soft tissues of slaughtered insects, or fragments of meat; while many ants feed indiscriminately upon any food that they have the luck to discover. Certain butterflies—our own purple emperor (*Apatura iris*) for example—are attracted by the odours and juices of putrefaction, while some caterpillars subsist upon substances of animal origin, such as wool, feathers, and wax. A few prey upon other insects. Those of a Southern European owl-moth (*Erastria scitula*) devour scale insects, and form protective cases from the shells of their victims mingled with their own excrement. The caterpillar of the common dun-bar moth (*Cosmia trapezina*), though it feeds normally upon oak and other leaves, is known to be an inveterate cannibal.

CHAPTER XII

PLANT-EATING INSECTS

A LITTLE reflection will convince the reader that all insects—indeed, all animals of every kind—are entirely dependent for food upon the vegetable kingdom, the reason being that of all living things green plants alone are empowered to build up food material from the simple chemical substances of the earth and air. To this rule there are no exceptions. Many predaceous insects feed directly upon vegetarian species; but even when they prey upon flesh-eaters, and these again upon other carnivorous kinds through several successive stages, we are sure to get back to plants in the end.

The number of insects which one kind of plant supports is often astonishing. It has been computed that the oak tree provides food and shelter for at least 1500 kinds, while some 500 more are attached to these as parasites. Probably the oak has an insect population greater than that of any other tree; but birches, elms, willows, poplars, and firs are all subject to the attacks of very many species. The same may be said of almost all cultivated plants. The apple has some 400 insect pensioners, not a few of which are harmful to the interests of mankind. Corn is attacked by about 200 species, fifty or more being notably injurious, while some twenty are devastating pests. Quite as many depend upon the clover if we include predaceous insects, parasites, and flower visitors. Nor are the poisonous plants exempt. The beautiful moth known as *Plusia moneta* feeds as a cater-

pillar upon the leaves of the monk's-hood—the most deadly of all the buttercup tribe; while the poison ivy (*Rhus toxicodendron*) is eaten by the caterpillars of at least three moths and the larva of a beetle.

Insects differ widely in their choice of vegetable food, and display preferences which are often unaccountable. Thus, a species may feed exclusively upon one plant, or at most upon a few closely related kinds. The caterpillars of the famous large copper butterfly (*Chrysophanus dispar*) appear to have fed only upon the leaves of the great water-dock, and this fact, in conjunction with the draining of the fen districts, goes far to explain the insect's total extinction, which was accomplished about the year 1860. The caterpillars of the large fritillary butterflies feed upon violet leaves throughout the wide range of the group in the temperate regions of the northern hemisphere, while those of the sulphur or brimstone butterflies are equally dependent upon buckthorn. On the other hand, certain insects will eat almost any kind of vegetation to which they have access. The caterpillars of the gipsy moth (*Psilura dispar*) have been observed, in a wild state, to feed indifferently upon seventy-eight species of plants. In captivity they ate 458 species, thirty under stress of hunger, the rest freely. Only nineteen species of those offered were refused, and most of these possessed highly poisonous or pungent juices, or were too tough to be bitten. Again, the migratory locusts are notoriously destructive; now, as of old, their invading armies "eat every herb of the land, and all the fruit of the trees."

While many insects browse openly among the foliage, others burrow between the upper and lower cuticles of leaves, and subsist upon the soft inner tissue, or parenchyma. Some of these leaf-miners form long, winding tunnels, the graceful curves of which are not displeasing

to the eye; others feed over a wide area, and give rise to unsightly, blister-like patches. The former method is adopted by the caterpillar of a little moth which burrows into bramble leaves, the latter by the maggot of a minute two-winged fly which often disfigures the foliage of the holly.

A whole host of insects penetrate the soil and attack the living roots of plants. Some of these, such as the caterpillars of the swift moths and the grubs of chafer beetles, do much damage; while the so-called wireworms are among the farmer's worst foes. Many other insects, aided by powerful dissolvent ferments which they secrete, subsist upon bark and wood. There is an old proverb which avers that to go between the oak and the rind is a practical impossibility; yet the grubs of many beetles feed just beneath the bast, or inner bark, and immediately above the surface of the wood. The parent insect makes a tunnel under the bark and deposits her eggs alternately on either side, while the grubs, when they hatch, burrow outwards to right and left, forming a characteristic pattern. The full-fed grubs pupate at the end of their burrows, and the perfect insects drill holes through the bark in order to effect their escape. These bark-boring beetles are thought to attack only sickly or newly-dead trees, but the caterpillars of certain moths burrow into the living wood. The case of the goat-moth (*Cossus ligniperda*) may be cited. The female lays her eggs in crevices of the bark, and the caterpillars penetrate the stem, in which they drive long tunnels. They continue for three years before they assume the pupa state, and in this period increase 72,000 times their original weight. It is hardly necessary to add that the goat-moth slowly destroys trees to which it gains access. The majority of wood-feeding insects, however, confine

their attacks to dead or dying trees, and thus act as vegetable scavengers. In this respect the great family of long-horn beetles (*Cerambycidæ*) is especially serviceable. We have only a few representatives in this country, but in the tropics the species are very numerous. "Probably no portion of the world" (writes the Rev. Canon Fowler) "contains a larger number than the densely timbered Amazon basin. In these great forests the Longicornia play a very important part in the economy of nature. As soon as a tree dies and begins to decay, their larvæ, which are very often of great size, attack it and bore it through and through; the work of boring from their large galleries is then taken up by various smaller species of wood-boring Coleoptera, and free access is thus given to the rain and moisture, which soon reduce the trunks to a pulp, and cause them not only to disappear, but to act as manure to those trees that take their places." But for the agency of these and other insects, the forests would gradually become blocked up with dead timber; for wood is a most enduring form of organic matter, and offers stubborn resistance to the ordinary processes of decay.

Termites, or "white ants," are another important group of wood-feeding insects. Their destructive habits often clash with the interests of mankind; but in Nature's scheme their work is wholly beneficial. The larvæ of wood-wasps (*Siricidæ*) also feed upon wood. The best known species is the giant wood-wasp (*Sirex gigas*), which is apt to alarm those who know nothing of its character. The insect is not uncommon in the British Islands, but it is much more abundant on the Continent. The female has a very hornet-like aspect, and carries a formidable ovipositor which is often mistaken for a sting. But this instrument is a tool, not a weapon. By its use the wood-wasp bores a hole through the bark of a sickly

fir tree, or one that has recently been felled, and lays her eggs in the solid wood, upon which the larvæ, when they hatch, commence to feed. They drive long burrows through the trunk, eating away the wood with their powerful jaws, and passing the fragments through their bodies. The wood-dust, scarcely altered in appearance by the digestive process to which it has been subjected, is packed tightly into the burrow behind the larva; so that the latter lives, as it were, within a cylindrical cell, which is gradually moved forward as the insect continues to feed. There is a good deal of conflicting evidence as to the duration of the *Sirex* larva's life, but this is probably not much less than two years. Moreover, after completing its transformation, a considerable interval may elapse before the perfect insect emerges. The full-fed larva of *Sirex gigas* is said to prepare the way for the exit of the imago by carrying its tunnel almost to the bark before changing to a pupa; but according to Fabre the European *Sirex augur* pupates in the heart of the trunk, and the adult insect has to cut its way through a considerable thickness of wood to the surface—a task which it is well able to accomplish. Instances are recorded in which these wood-wasps have actually gnawed their way through a sheeting of lead with which baulks of wood had been covered. Owing to their habit of lying up in timber for indefinite periods, these insects sometimes appear in the most unexpected places. Dr. Sharp relates that "large numbers of a species of *Sirex* emerged in a house in this country some years after it was built, to the great terror of the inhabitants. The wood in this case was supposed to have been brought from Canada."

Besides feeding largely upon wood, insects consume all manner of decaying vegetable matter. In this way

they not only assist sanitation in all parts of the world, but also promote the speedy transmutation of effete organic matter into its simple chemical constituents. Indeed, the importance of insects as agents in this necessary resolving process can hardly be exaggerated. As we have seen, the raw material which goes to form organic bodies is built up in the first instance by green plants. But it is only lent for the purpose, so to speak, and as soon as it has served its turn putrefaction sets in. In other words, the once living matter is reconverted by ordered stages into those inanimate substances of which it was originally formed. Sir Ray Lankester tells us that "this breaking down of the chemical compounds of dead bodies into a condition in which they can serve as the food of plants is effected by excessively minute, but ubiquitous and enormously abundant colourless organisms—the actual chemical agents of putrescence and fermentation—known as bacteria. Were there no bacteria, the nitrogen and carbon of dead plants and animals would remain locked up as proteid, fat, and sugar. The surface of the earth would be strewn—even covered in—by the enormous accumulation of dead, unchanging bodies, and then life would become extinct, for there would be no food for the green plants." But while this is true, it is also a fact that bacteria, notwithstanding their abundance, would be unable to perform their task without the intervention of insects. The latter, by comminuting the tough fibres of dead plants, constitute a kind of "speeding up" agency whereby the ultimate dissolution by bacteria is greatly accelerated. Moreover, the destruction of living plants by insects is doubtless part of the same great scheme, and beneficial in the main to the world at large. Mr. R. B. Henderson has suggested that, but for the voracity of grubs and caterpillars, probably "too many leaves would

be left to die in the ordinary course of events, and too many bacteria would be called into being to remove so much dead vegetable matter. Too many bacteria might result in great havoc being wrought in the animal kingdom, with, ultimately, results no less disastrous to the vegetable world itself; for it is a remarkable fact, never to be forgotten in dealing with terrestrial life as a whole, that animals are quite as necessary for the existence of plants as plants are for animals."

Besides the roots, stems, and foliage of plants, not a few insects consume the parts of the flower. Certain small caterpillars and beetles feed by preference upon the petals, while others destroy the essential organs. Among the latter, the apple blossom weevil (*Anthonomus pomorum*) has gained a world-wide notoriety on account of its depredations in orchards. The female insect punctures a flower bud with her rostrum, inserts an egg, and then carefully closes the hole that she has made. The larva feeds upon the stamens and pistil of the incipient blossom, thus destroying its power of fructification. Indeed, the petals never expand, but turn brown as though they had been nipped by frost. The larva changes to a pupa within the bud, from which the perfect weevil eventually escapes, leaving a tell-tale hole to mark the place of its exit.

Many other insects attack fruit or seeds. Among these the codlin moth (*Carpocapsa pomonella*) is one of the best known. It appears about the end of May, and flies at dusk from tree to tree, laying its minute eggs singly in the "eyes" of newly formed apples when they are about an inch in diameter. When the tiny caterpillar hatches, it burrows into the fruit, where it feeds chiefly upon the pips and core. When full-grown, it tunnels to the rind, and effects its escape, hiding beneath moss, or

in crevices of the bark, during the winter. At the first approach of spring it spins its cocoon and changes to the pupa from which the adult moth emerges in due course. The so-called "maggots," which are often found when a pea-pod is split open, are usually the caterpillars of a small moth (*Grapholitha pisana*), closely allied to the codlin moth. These issue from the pod when they are full-fed, and turn to pupæ in the soil, where they remain throughout the winter. The caterpillars of certain small moths of the same widely distributed family (*Tortricidæ*) have achieved fame under the guise of "jumping beans." There are at least two species of these insects, found in the United States and Mexico.

Probably the reader has suffered the unpleasant experience of cracking a filbert or cob nut, only to find within a fat white grub and a much-damaged kernel; and it may have occurred to him to wonder how the culprit obtained access to its snug quarters. The explanation is really quite simple. Its parent, the nut-weevil (*Balaninus nucum*), bores a hole with her long rostrum in a young nut, and inserts her egg. As the nut develops and the shell hardens, all trace of the injury is obliterated. But the grub within feeds sumptuously upon the kernel. In the autumn it bores a small round hole through the shell, drops to the ground, hibernates beneath the soil, and changes to a pupa in the early spring. The pea beetle (*Bruchus pisi*) is another seed-destroying insect. The female lays her eggs on the pods when they are very young, and the grub on hatching bores through the pod and into a pea, where it finds sufficient nourishment for its development. It eventually pupates in the pea, having first eaten its way to the outer coat, so that when the adult beetle matures it has only to break its way through a thin skin. An allied species of *Bruchus* is said to

Marble Galls, on Oak, caused by the Gall-wasp *Cynips kollari.* (Inset) The insect, greatly magnified

Horse-bean Galls, on leaves of Crack Willow, caused by the Saw-fly *Nematus gallicola*

require two seeds to enable it to complete its growth. After consuming one, it drops to the earth, and (being a legless maggot) drags itself along by its jaws until it comes to another pod, into which its bites its way.

Not a few insects are able to modify the growth of plants in such a way that an excrescence, called a gall, is formed. This power is not confined to one family. Certain species of aphides, thrips, scale insects, two-winged flies, beetles, as well as numerous Hymenopterous insects and the caterpillars of a few small moths all produce characteristic gall-structures; while the bright scarlet "horse-bean galls," which are often so abundant on the leaves of the crack willow, are the work of a saw-fly called *Nematus gallicola*. During April and May the parent insect lays her eggs, by means of her wonderful twin-saw ovipositor, within the leaf buds; and as the leaves unroll, the galls develop. For several weeks each remains a solid mass of vegetable tissue, with the egg lying in a small cavity near the centre. Then the larva hatches, and feeds upon the inner portion of the gall, from which, when full-fed, it issues and drops to the ground. Here it forms a cocoon, changes to a pupa, and ultimately appears as a perfect saw-fly. This happens in August or early September; and each newly emerged female saw-fly oviposits at once in developing leaf buds, with the result that a second batch of galls shortly appears. Thus, the saw-fly achieves two complete life-cycles in the course of each twelve months.

Professor Carpenter has pointed out that the production of a gall seems calculated to supply the wants of the insect with as little damage as possible to the plant. We may appreciate this economy by comparing the habits of *Nematus gallicola* with those of another species of the same genus well known to gardeners as

the gooseberry saw-fly. In the former case the damage done to the willow tree is slight, even when the insect is present in force. Each larva is confined throughout life to one small part of the leaf—namely the gall; and although the formation and upkeep of this structure imposes a tax upon the tree's resources, the bulk of the foliage remains to make good this loss. But the larvæ of the gooseberry saw-fly (*N. ribesii*), not being confined to galls, consumes one leaf after another with startling voracity. A few hundreds of these caterpillars will quickly strip the foliage from a plantation of gooseberry and currant bushes, seriously affecting their vitality and growth. Nevertheless, while the *raison d'être* of galls is fairly obvious, in that Nature delights to foster any scheme for mutual economy, the origin of the individual gall is by no means easy to explain. Pliny thought that galls were fungi, in which insects bred by chance. A later author opined that the parent insect laid its eggs in the soil, whence they were drawn up with the sap to the leaves where the galls were found. Redi actually assumed that the plant had a vegetable soul, this vegetable soul presiding at the origin of galls, with the eggs, larvæ and imagines, while it again gave issue to fruits—whatever this jargon may signify. Yet he had himself successfully refuted the theory of spontaneous generation which was current in his day! A more modern notion, and one which until recently evoked universal credence, is that the parent insect infects the plant tissue during oviposition by injecting a small drop of poisonous fluid, and that this gives rise to a morbid enlargement and subdivision of the vegetable cells.

It is a fact that gall-insects often inject a drop of fluid into the wounds which they make, but they do this either to provide a lubricant for the working of their

"Bedeguar" gall, on wild rose, caused by *Rhodites rosæ*. Britain

ovipositors, or as a varnish to seal up the injury—certainly not to poison the tissue. Various careful observations have proved (in the case of the true gall-wasps of the family *Cynipidæ*) that the growth of the gall structure does not commence until after the advent of the larva, even though hatching may be postponed for a considerable period; and that the stimulus to unhealthy growth on the part of the plant is furnished by the gnawings, possibly also by the secretions, of the tiny grubs. With the saw-flies, as we have seen, the growth of the gall is complete, or far advanced, before the egg hatches; but in these cases it is known that the egg itself undergoes changes, and increases in size, and thus probably supplies the irritation which determines the production of a gall.

At first thought it may seem incredible that the mere swelling of the egg, or the gnawing of a microscopic grub, should supply the impetus to abnormal growth. But the egg is invariably laid in contact with what botanists term cambium or meristem tissue—that is to say, the particular layers of vigorous cells whose active multiplication by fission brings about the phenomenon which we call "the growth of the plant." These cells are extraordinarily sensitive, and the presence of foreign bodies—*i.e.* the eggs or grubs—excites them to irregular and excessive growths. This much we know. But why galls invariably "come true" remains a mystery. For each of the many kinds of gall insects known to science is bred from a perfectly distinct and characteristic gall. Take for example the three familiar kinds formed on the leaves of the wild rose by members of the genus *Rhodites*. The three gall-wasps concerned are closely related. Yet the galls from which they come are widely different. First there is the familiar "bedeguar," or "robin's pin-cushion," the work of the little gall-wasp *Rhodites rosæ*. It is

a kind of community, consisting of a number of cells, each containg a larva, the whole mass being clothed with long, red fibres which are probably due to the abortive efforts of the plant cells to produce leaves. Secondly, the species called *Rhodites eglanteriæ* forms one-chambered galls, about the size of a pea, upon the underside of the leaves; while the third species, *Rhodites nervosus*, comes from a gall which is distinguished by thorn-like projections that spring from its surface, like spikes on a mediæval war club. Almost any hedge in the south of England will supply specimens of these three galls, so that the reader may readily compare them, and breed from them their respective tenants.

Numerous Cynipid galls are found on the oak. "King Charles's apples" originate in the buds; "truffle galls" grow from the roots and are sometimes embedded several inches in the soil; many other species, differing widely in form, spring from the leaves; while at least two kinds hang like currants from the catkins. All these diverse forms of galls originate in the oviposition of an insect. Apparently the operation of egg-laying is performed in the same manner in every case; so that we are left to surmise that each kind of gall-larva gnaws the cells in a manner quite different from that adopted by all other kinds. The insect when first hatched is so minute that it can only be watched through the microscope, and the precise manner in which it attacks the cells remains a mystery. Yet it is probable that whereas the plant makes the gall, in so far as the supply of constructive energy is concerned, the tiny grub (or, in certain cases, the developing and enlarging egg), by its peculiar method of irritating the sensitive cells, determines the form which the gall shall take.

Among the *Cynipidæ* occurs that remarkable pheno-

Galls on Wild Rose leaf caused by *Rhodites nervosus*

Galls on Wild Rose leaf caused by *Rhodites eglanteriæ*

PLATE XXXII

Currant Galls (*Spathegaster baccarum*) on catkins of Oak

Spangle Galls (*Neuroterus lenticularis*) on underside of Oak leaf

menon which has been termed "alternation of generation." It may be conveniently studied in the life-history of the "spangle gall-wasp." Spangle galls appear in enormous numbers on the underside of oak leaves in July. They are small, button-like objects, usually pale yellow, though sometimes brownish-red in colour, and are covered densely with radiating stellate hairs. In September, or early October, they fall to the ground, where they lie literally by millions among the grass stems, in wheel ruts through the woodlands, and in holes and crannies of the earth. Here they remain throughout the winter, and it is remarkable that they do not suffer loss in their severance from the leaves. Indeed, each spangle gall may now be regarded as an independent atom of vegetable life. The cells of which it is formed remain capable of absorbing moisture. Thus, during the winter, the galls swell up, become more strongly obtuse, and increase considerably in bulk. The larva lies snugly in its chambers at the centre of the gall, secure from frosts and biting winds, and surrounded by a plentiful supply of food. In these happy circumstances it continues to feed throughout the winter, and changes to the pupa in March. Towards the end of this month the mature insect cuts its way out of the gall.

And now we come to a very remarkable fact, namely, that no one has ever reared a male insect from a spangle gall. If males ever existed, they must have become extinct long ages before naturalists began to unravel the mysterious life-histories of gall-insects in general. How and why this state of things came about it is impossible to conjecture; but the fact remains that the gall-wasps which issue from spangle galls are all "bachelor women" and never go courting, for the sufficient reason that their world contains no *beaux*. Nevertheless—and herein lies

the most surprising fact of the whole amazing story—they are by no means exempt from the duties of maternity. Each female flies confidently to her old foster-mother the oak tree, and by means of the long ovipositor with which she is equipped, thrusts her eggs into the very heart of a bud, right down among the embryo leaves and catkins.

In the case of an ordinary insect, the life-cycle would end with the egg-laying of the adult. To continue our observations would merely be to verify facts which we had already noted. Not so, however, with these gall-wasps. One can never be quite sure that their life-history is complete until one actually traces it through to a repetition. Let us therefore observe the unfolding of an oak bud in which the spangle gall-wasp has laid her eggs. We shall find that galls are produced upon the catkins as well as upon the leaves; but they are not in the least like spangle galls. In size and appearance they resemble so many currants—at first green, but mellowing under the influence of sunlight to a ripe crimson. The sight of these galls comes as a severe blow to our cut and dried theory that like invariably produces like; for the lineal descendants of spangle galls have produced currant galls, and this is their invariable custom. Moreover, when in due course the second generation appears in May, we find that it comprises both males and females, and that the insects are quite different from those of the agamic brood. Notably, the females lack long ovipositors—implements which would be superfluous, because these summer gall-wasps lay their eggs beneath the cuticle of the leaf, and have no tightly packed buds to deal with. These insects, in fact, give rise to a new generation of spangle galls; and so this wonderful alternation of generation—this interchange of personality—continues year after year. These facts were not known to the early naturalists, who

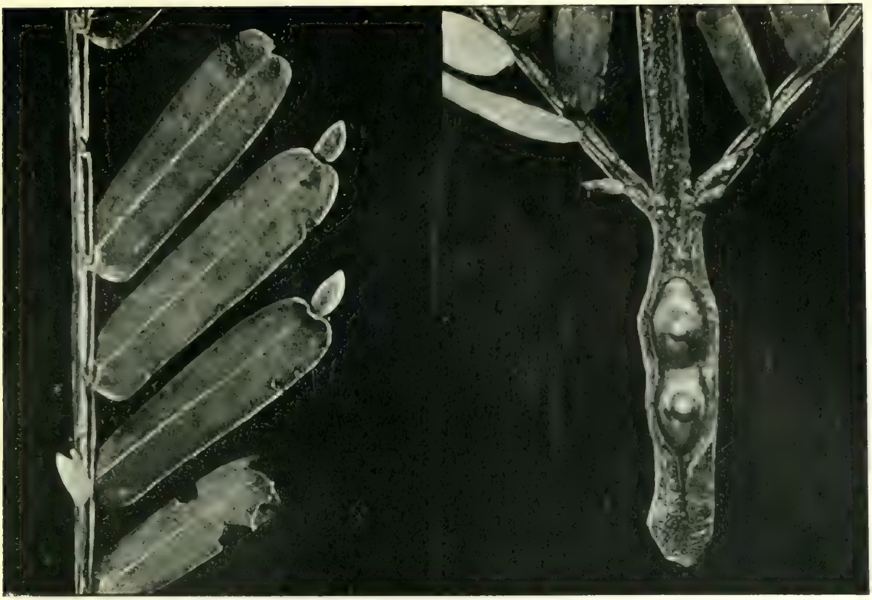
gave the insects which emerge from each kind of gall a different name, calling the spangle gall-wasp *Neuroterus lenticularis*, and its currant gall form *Spathegaster baccarum.* For the sake of convenience these names are still retained; we must bear in mind, however, that they do not designate two different kinds of insect, but merely two alternating forms of the same species.

A phenomenon so remarkable as alternation of generation has naturally given rise to much discussion and theorising; but so far no adequate explanation of the fact has been advanced. Moreover, the case of the marble gall-wasp (*Cynips kollari*) is even more astonishing and mysterious. This species has only one generation in the year, and every individual is a female. No male has ever been discovered, although from time to time entomologists have bred many thousands of specimens in captivity, Among British gall-wasps, therefore, we find (1) species (such as those of the wild rose mentioned above) with only one generation, but having males and females; (2) species such as *Cynips kollari* with one generation and no males; (3) species with two generations, the one agamic and the other sexual. Observation of the first group has shown that at least in certain species parthenogenesis is undoubtedly prevalent. In the case of the bedeguar gall-wasp, for example, it is probably the rule, seeing that the males of this insect are excessively rare. We may suppose, therefore, that the males tend to disappear as the faculty of virgin reproduction increases; and thus we find a possible clue to the mystery of the marble gall-wasp, which, as we have seen, has no males at all. But in the present state of our knowledge it seems impossible to explain adequately the phenomenon of an agamic generation alternating with a sexual one. The entomologist Adler, who devoted much time and thought to this

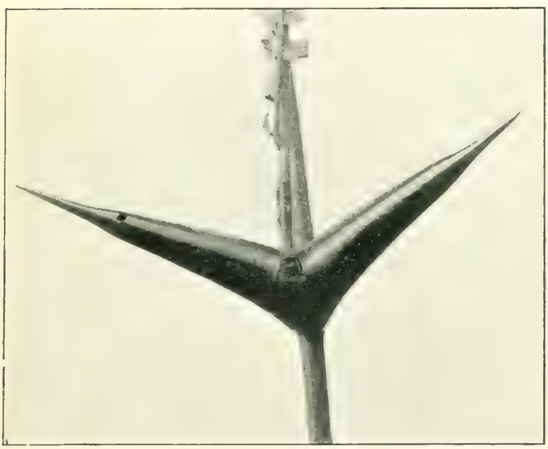
problem, adduced physiological evidence which indicates that the agamic generation originally possessed males; but why complete parthenogenesis has supervened, and for what reason alternation of generation became established (in preference to the simple double-brood principle which obtains commonly among other insects) are problems for the future.

The associations of ants with plants are sometimes so intimate that they suggest actual symbiosis, or mutual benefit. Belt found several species of Acacia in Nicaragua and the Amazon valley which are admirably adapted to the needs of certain small ants of the genus *Pseudomyrma.* The trees in question bear large, hollow thorns which the ants penetrate by boring a hole near the apex; and in these thorns the insects habitually live and breed. Further, the tree supplies food as well as shelter for its insect population. Glands at the bases of the leaf-stalks secrete a sugary fluid, while many of the leaflets are tipped with small sausage-shaped masses known as "Belt's bodies." These are rich in albumen and are easily broken off. They are systematically collected and eaten by the ants, which appear to subsist exclusively upon the two kinds of food which the tree provides. Other ants are similarly attached to young Cecropia plants in Central America and Brazil. In these trees there is a small depression just above the insertion of each leaf-stalk where the rind is much thinner than elsewhere. A female ant effects an entrance at this weak spot, and sets up housekeeping within an internodal chamber of the stem. Meanwhile the hole becomes closed by an excrescence from its margin, and the ant is held prisoner until she has reared about a dozen workers. The latter then re-open the orifice from within, and keep it open, so that the members of the community may come and go as their needs dictate.

PLATE XXXIII



Acacia sphærocephala: an Ant plant: showing "Belt's bodies" on tips of two leaflets (to left), and glands at base of leaf stalk (to right)



Acacia sphærocephala: hollow thorns which are penetrated by Ants

Pseudomyrma bicolor: an Ant which is associated with *Acacia sphærocephala* (greatly magnified)

The workers also establish communication between the internodal chambers by boring through the septa or partitions. They seldom or never leave the tree, which itself supplies them with food in the form of little egg-shaped bodies which are produced just below the bases of the leaf-stalks. The ants detach these as they ripen, and either eat them immediately, or store them in the hollow chambers of the stem for future use. When these egg-shaped bodies are present in numbers on a tree, it is a sure sign that the ants, which belong to the genus *Azteca*, are not in residence.

Not the least remarkable fact connected with these ants of the Acacia and Cecropia is that they actually protect their trees from the ravages of leaf-cutting ants and other marauders. Despite their diminutive size, the tree-dwellers are very fierce and pugnacious, and will not tolerate trespass upon their domains. "So soon as this standing army of ants detects the foe" (writes the great botanist Anton Kerner von Marilaun) "it commences offensive operations, like the garrison of a fortress, and by biting and squirting formic acid frightens the invader away." These interrelations of ants and plants have doubtless been gradually perfected, in the course of ages, through the agency of natural selection. In tropical America, leaf-cutting ants are a terrible scourge, and can strip a tree of its foliage in the space of a few hours. Clearly, therefore, a tree which possessed a large and easily satisfied ant-garrison, bent upon keeping intruders at bay, would be more likely to survive than another of the same species to which no such ants resorted. Thus, any variation on the part of a tree calculated to attract ants of the right sort would tend to be established and perfected. These marvellous interrelations probably arose in some such manner; but to say that the ants

protect their host-trees in return for the food and shelter which they receive would be to endow these insects with a power of reasoning which assuredly they do not possess.

In Java, there are some curious epiphytic plants which produce large bulb-like excrescences, the chambers of which are usually tenanted by ants; but these swellings are really water-reservoirs, and are not primarily connected with insects. Nevertheless, the ants rush forth when disturbed, and there is some reason for thinking that the plant may derive benefit from their presence. That ants guard and protect certain flowers is a well-established fact, commented upon by Kerner. The young flower-heads, or capitula, of certain thistle-like plants indigenous to southern Europe are particularly liable to the attacks of beetles, which bite big holes in the heads, and thus work much injury. "Honey is secreted from big stomata on the imbricating scales of the still-closed capitula in such quantities that one can see a drop of it on every scale in the early morning, whilst later in the day, as the water evaporates, little masses, or even crystals, of sugar are to be found. This sugar, either in its liquid or solid form, is very palatable to the ants, which habitually resort to these capitula during the period of its secretion. And to preserve it for themselves they resent any invasion from outside. If one of the beetles appears they assume a menacing attitude. They hold on to the involucral scales with their last pair of legs and present their fore-legs, abdomen, and powerful jaws to the enemy. Thus they remain till the beetle withdraws, if necessary hastening its retreat by squirting formic acid in its direction. Then they quietly begin to feed on the honey again. . . . As soon as the florets on the heads begin to open, the secretion of honey diminishes and ultimately ceases. No longer do beetles come to devour them, nor is there any further

need for protection. The garrison is withdrawn, the ants going away in search of other, younger flower-heads."

Many bugs, as well as all kinds of aphides and scale insects, subsist upon sap. We have seen that their mouth-parts have been changed into piercing and sucking organs, whereby they are able to puncture the cuticle of leaves and stems, and absorb the sweet juices of the plant. One would imagine that such a method of feeding would invariably conduce to a sedentary condition of life; but this is by no means always the case. Many species of aphides migrate periodically from one kind of plant to another without any apparent reason. The life-cycle of a typical aphid may be roughly summarised as follows: Eggs are laid in the autumn. From these, in the following spring, young nymphs hatch, which are all females. They rapidly complete their metamorphosis, and when adult produce living young, which are also all females. Successive generations of viviparous females appear, some being wingless, while others are winged and capable of flying to other plants. The final generation of the year comprises both males and females—the latter laying the eggs which are destined to start the next year's attack. The appearance of winged individuals is often correlated with a remarkable change of habit, these forms migrating to plants which may be of a quite different kind from those on which the wingless broods were reared. Thus the winged females of the hop aphid often fly in autumn to sloe, damson, or plum trees, on the twigs of which they deposit their eggs; while the nymphs which hatch from these eggs ultimately attain wings and fly back to the hop, where they reproduce living young for ten or twelve generations before fresh winged forms are developed. Similarly, an aphid of the apple, after producing several wingless generations, gives rise to winged individuals that

migrate to the stems of corn or grass, on which plants another cycle of generations is produced. In the genus *Chermes*, which frequents conifers, very complicated life-cycles appear to be the rule. The successive generations of the species known as *Chermes abietis* have been investigated by Continental observers, and may be briefly tabulated as follows:—

First. A wingless, parthenogenetic female hibernates on the spruce or Christmas tree, and in the spring lays numerous eggs at the tip of a young shoot, thus giving rise to the familiar pine-apple gall, or false cone.

Second. The young that hatch from these eggs develop in the cavities of the gall, and after their final moult become winged females—a few of which remain on the spruce, where they lay their eggs. From these eggs are produced young that grow into wingless, hibernating females, which next year produce galls exactly as their grandmothers did. But many individuals of this (the second) generation migrate to the larch tree, where they lay their eggs on the leaves or "needles."

Third. These eggs give rise to a third generation of wingless, parthenogenetic females which resemble their grandmother—*i.e.* the foundress of the series. They hibernate on the trunk of the tree, and protect themselves by a waxy secretion which, from a distance, has the appearance of frozen sleet. In the spring they lay their eggs upon their "intermediate conifer," the larch, but no gall is formed.

Fourth. These eggs give rise to the fourth generation, which is dimorphic, being composed of (1) wingless individuals like the parent form, thus resembling their great-grandmother, and (2) winged forms resembling those of the second generation. The former lay their eggs on the larch, and thus give rise to a wingless stock which

may flourish indefinitely on this tree. But the latter fly back to the spruce, on which they lay their eggs.

Fifth. The young that hatch from these eggs develop into a winged generation comprising both males and females. After pairing, each of the latter lays in midsummer a single egg on the spruce, from which emerges a wingless, hibernating foundress of the original type.

Thus this fivefold life-cycle requires two years, and two different coniferous trees for its completion, while parallel series of unisexual (female) generations may be established, the possible continuance of which has not yet been determined. If we arrange the facts in the form of a genealogical tree, we get the following:—

Wingless Female
(forms gall on spruce).

Winged Females
(resident on spruce).

Wingless Females
(form galls on spruce).

Winged Females
(migrate to larch).

Wingless Females
(resident on larch).

Wingless Females
(continue on larch).

Winged Females
(fly back to spruce).

Winged Males and Females
(resident on spruce).

Wingless Females
(form galls on spruce).

Closely allied to *Chermes* is the dreaded *Phylloxera*—a small aphid which was introduced from North America

to Europe, where, especially in France, it has caused incalculable damage in vineyards. The life-cycle of this insect is no less complex than that of *Chermes*, but the various generations migrate between the leaves and the roots of the same plant—the vine—and not from one kind of plant to another. Gall structures are formed both on the leaves and the roots. An allied aphid known as *Phylloxera punctata* may be found in England on the underside of oak leaves. This is probably the only congener of the vine *Phylloxera*, and Lichtenstein says that "in its cycle, from the starting-point of the winter-egg to the assumption of the sexual condition, it exhibits a series of no less than twenty-one forms."

Many kinds of aphides and their allies produce large quantities of a sweet liquid to which the name "honey-dew" is usually applied. It appears in drops from the end of the abdomen. In some species an individual has been observed to emit as many as forty-eight drops, each about 1 mm. in diameter, in the course of twenty-four hours. Honey-dew accumulates as a sticky deposit on the leaves of plants, and is eagerly sought after by many kinds of insects, especially ants. Indeed, ants have discovered the origin of the sweet food, and actually obtain it direct from the aphides, which on this account have been called their "cows." One may watch them running about among a flock of aphides, and eagerly seizing the glistening drops as they exude; while there is reason for thinking that an aphid voluntarily surrenders its store of sweetness in response to the caress of an ant's antennæ. Ants are essentially mandibulate insects. They can bite and they can lick; but they have no elaborate piercing and pumping apparatus like an aphid, no complex "tongue" like a bee, no sucking-tube like a moth. Thus, to obtain the sweet juices which constitute so large a part of their

food, they rely largely upon the exudations of plants, or of other insects. Not only aphides, but certain scale insects and other members of the sub-order Homoptera provide secretions of which ants are very fond.

Nectar and pollen form the staple food supplied by bees to their young; but these sweet and delicate substances are rarely sought after by nomadic larvæ. Indeed, to profit by the dainty banquets which the flowers provide, an insect must be gifted with exceptional qualifications. Thus we find that most flower-frequenting species possess, in addition to their highly specialised mouth-parts, unusually large eyes and brains; while their muscular control is remarkably sustained and delicate. The interrelations of insects and flowers are so complex, however, that we must deal with them in a separate chapter.

CHAPTER XIII

INSECTS AND FLOWERS

All those who have lingered observantly in gardens or country places must have noticed that flowers are much frequented by insects, more especially by bees which fly from the apiaries of the district. In popular parlance bees are said to visit flowers in search of honey; but this is less than half the truth. What bees really gather is the sweet juice, called nectar, which the plants secrete. Now nectar belongs to the special group of sugars known technically as "sucroses" or cane-sugars. The bee sucks this nectar into its crop, whence it is regurgitated when the insect returns to the hive. But in the short interval the nectar becomes chemically changed by admixture with peptic secretions. Its sweetness is converted from cane-sugar into "glucose" or grape-sugar; and not until this change has taken place does it become "honey" in the strict sense of the word. Again, bees do not frequent flowers solely for the sake of nectar; they go also to gather pollen, which figures prominently in the regimen of the hive. The bee collects pollen in the first instance among the hairs of its body and legs, sometimes incidentally, often by a deliberate process of wallowing among the stamens. The pollen is then raked from the hairs by means of the "pollen combs" of the hind-legs (see page 55), and packed upon the "pollen baskets" or corbicula. Exactly how this packing is accomplished is not definitely known; but there is reason for thinking that the bee, by crossing its legs, transfers the pollen from

one set of combs to the basket of the opposite leg, the stiff hairs on the hind-margin of the planta serving to scrape the pollen from the combs. If we watch a bee that has just left flowers from which it has gathered pollen, we shall see that it hovers in the air for a few seconds; and those who possess keen vision will see that it makes swift passes with its legs. It is, in fact, combing the pollen grains from its hairs, and transferring them to the baskets; but its movements are so extremely rapid that their precise sequence eludes the eye. When it reaches the hive, the bee thrusts its hind-legs into a cell, and removes the masses of pollen from the corbicula by means of the tibial spurs of the middle legs. Mixed with honey, the pollen is used to feed the rising generation of grubs. But the worker bees cannot reach all parts of their bodies with their legs, and some pollen is sure to be left sticking to the hairs. These stray grains are of prime importance from the point of view of the plant, for they may be carried from one flower to another of the same kind where they are likely to set going the process of seed or fruit production. Thus, in their visits to flowers, bees and other insects perform an unconscious service to the plants.

A little knowledge is said to be a dangerous thing; but a little knowledge of botany is indispensable if we wish to comprehend the relationships which exist between insects and flowers. We must know what a flower really is, the functions of its various parts, and the names by which they are distinguished. The late Grant Allen, in a quaint phrase, called flowers "the husbands and wives of plants." Without flowers, plants would be, if not sterile in the fullest sense of the term, at least deprived of their most effective means of reproduction.

Of course there is a whole class of flowerless plants the

increase of which is governed by other laws; but in the case of the plants with which we are now concerned, flowers are the crown and climax of all effort.

A flower consists essentially of two parts, or sets of parts. If we take a buttercup, for example, we find in its centre a group of small, green bodies. These are the *carpels*, which together make up the female element of the flower. Each carpel comprises a lower portion called the *ovary*, because it contains the ovule or potential seed; and a narrower upper portion known as the *style*, which terminates in a small receptive tip called the *stigma*. But the carpels are rarely separate from one another, or so numerous, as they are in the buttercup. Usually they are more or less completely united to form a single organ, the union being often so intimate that the actual number of carpels present is only indicated by the lobing of the stigma and the chambers of the ovary. Thus, in descriptions of flowers, the female element is generally referred to collectively as the *pistil*. Surrounding the pistil in the buttercup we find the male element of the flower—the numerous closely-set *stamens*. Each consists of a stalk, called the *filament*, which bears at its summit a flattened knob termed the *anther*. Each anther is made up of two lobes joined together by a kind of cross-piece, continuous with the filament and called the *connective;* while each lobe contains two cavities within which the *pollen* is produced. When ripe, the anthers rupture, and the pollen is shed.

In addition to these indispensable floral elements there are commonly two whorls of leaf-like structures. Those of the inner whorl are termed *petals;* they are often brightly coloured, and together make up the *corolla*. Those of the outer whorl are termed *sepals;* they are commonly green, and are spoken of collectively as the

calyx. In flowers of the lily type—tulips, orchids, irises, &c.—the parts of the two whorls (representing the calyx and the corolla) are usually all coloured; and botanists call the separate parts *leaves* and the whole structure a *perianth*. When the parts of any whorl are all alike in shape, size and arrangement, the whole is said to be *regular;* but when one or more parts are in any way different from the rest, the whorl is *irregular*—these terms being usually applied to the whole flower. Thus, while the buttercup, wild rose and primrose are regular flowers, the pea, white dead-nettle and figwort are irregular. Not infrequently, a flower is furnished with special glands, or *nectaries*. These are found exactly where the proboscis of an insect which is adapted for the purpose can reach them. "In regular flowers" (writes the Rev. G. Henslow), "which can be approached from all points of the compass, the rule is that the nectar is secreted all round the base of the flower, or by every petal, &c., as the case may be; but in irregular flowers, which are almost invariably situated close to the stem, so that they can be visited on one side only, the usually single gland is just where the proboscis can best reach it, and nowhere else."

Pollination consists in the transfer of pollen from the anthers to the stigma of the pistil. In this way fertilisation is effected, the seeds are "set," and the plant becomes fruitful. Some flowers, however, do not combine the sexes in one bloom; they are wholly male, or wholly female. In such cases a transfer of pollen by some agency external to the plant is clearly indispensable; while there are many bisexual flowers in which self-pollination is equally impossible, either on account of some structural disability, or because the anthers and stigma do not ripen at the same time. These points will become clearer as we proceed,

but the reader should at once fix in his mind the fact that a vast number of plants only escape barrenness through the intervention of circumstances over which they exercise no direct control.

Dry, dust-like pollen is carried about by wind, many kinds of trees and grasses being thus cross-fertilised. They have inconspicuous flowers—almost without exception. On the other hand, plants whose flowers have bright-coloured petals and fragrant scents rely chiefly upon the assistance of insects; and their pollen is usually more or less adhesive. Probably insects began to visit inconspicuous flowers at a very remote period of the world's history; for they are adventurous creatures, alert to discover fresh sources of food. That these primitive flower-visitors instituted the system of cross-pollination which obtains to-day seems certain. The stages of the wonderful evolutionary process which must have followed can only be guessed at; but the secretion by plants of nectar in the region of the essential organs marked a great step in advance. The sweet liquid constituted a counter attraction to the insects, which thus devoured less of the valuable pollen, albeit they did not carry less of it away upon their hairs. Indeed, at the present day, many kinds of insects visit flowers solely for the sake of nectar, and eat no pollen at all.

In the case of the buttercup, pollination is a relatively simple process. Many insects, especially two-winged flies, visit the flower, which is rendered conspicuous by its yellow petals. The flies feed, according to their taste, either upon the pollen or upon the nectar which is secreted at the bases of the petals. Some of the pollen may be transferred to the stigmas of the same flower, while some may be carried to the flowers of a distant plant, the chances in favour of self- and cross-pollination being about equal. We may contrast the buttercup with

that beautiful water-plant the arrow-head (*Sagittaria sagittifolia*), in which the sexes are separate. The flowers are arranged on an upright stem in whorls of three, the lower being females, the upper males. As they open from below upwards, self-pollination is clearly impossible; but when the female flowers mature, they are fertilised by insects which bring pollen from the male flowers of plants in a more advanced state. Later, the male flowers expand, and their pollen is in turn transferred to the female flowers of other plants. The arrow-head also affords an interesting example of isolation by water. Insects that come through the air for nectar and pollen are welcome visitors, but creeping insects, which can be of little service to the plant, are kept back by the water. We shall see later that the problem of frustrating useless visitors often influences the structure of the flower itself.

Unlike the flowers of the arrow-head, those of the rose-bay willow-herb (*Epilobium angustifolium*) are bisexual; yet, as was first observed by the botanist Sprengel in 1790, the plant cannot dispense with the assistance of insects, because the stamens and pistil do not ripen simultaneously. The conspicuous rose-coloured flowers are borne in long, terminal clusters, and are much frequented by insects, especially bees. When the flower first opens, the style of the pistil bends downwards, while the stamens stand up in the centre. During the process of pollen-shedding, which occupies several days, the fourfold stigma gradually expands, and is raised by the straightening of the style until it projects from the centre of the flower. In flowers of the earlier stage, the protruding stamens form a convenient alighting place for the insect visitor, which gets dusted with pollen on the under surface of its body as it sucks the nectar which is secreted by the upper surface of the ovary. On passing to a flower in the later

stage, however, the bee alights of necessity upon the stigma, which projects in the place previously occupied by the anthers, the latter being now bent aside. Thus pollen brought from the younger flower is transferred to the stigma of the older.

In the common primrose (*Primula vulgaris*) cross-pollination is secured by a different plan. The five petals are united at their bases to form a tubular corolla, and the flowers are dimorphic. In one form, known popularly as "thrum-eyed," the pistil has a short style, while the anthers of the stamens are situated at the mouth of the corolla tube; in the other form, called "pin-eyed," the arrangement is reversed. The style is long, the globular stigma is in the mouth of the tube, while the anthers are low down—being on the same level as the stigma in the "thrum-eyed" flowers. The two forms of flower are not found on the same plant. Long-tongued flies, and occasionally humble-bees, visit primroses in search of the nectar which is secreted at the base of the ovary—*i.e.* at the far end of the corolla tube. When an insect comes to a long-styled flower, its proboscis is dusted with pollen at a part which—if it subsequently visits one with a short style—is brought into contact with the stigma. Conversely, pollen collected from the anthers of a short-styled flower is transferred to the stigma of a long-styled form. The flowers of the primrose may sometimes be self-fertilised, as when pollen falls upon the stigma of the short-styled form; but cross-pollination can only be effected through the agency of insects.

While some kinds of flowers are accessible to insects of many kinds, the majority are specially reserved, so to speak, for the delectation of a few species. Thus, the red clover relies upon the aid of humble-bees with mouth-parts sufficiently long to penetrate its floral tube; and

Darwin showed long ago that this plant is sterile when protected from the visits of these insects. The small flowers of the ivy and red-currant have each a kind of central cushion whereon the nectar glistens in profusion. Apparently it is free to be sipped by all and sundry. Yet in point of fact it is only accessible to "short-tongued" insects—those with long suctorial mouth-parts, such as butterflies, moths, and humble-bees, being in much the same case as the fabled stork to whom the fox offered food in a shallow dish. Many flowers, however, cater exclusively for "long-tongued" insects. This is the case with the honeysuckle (*Lonicera periclymenum*). The inflorescence consists of a number of closely crowded blooms, each of which has a long tubular portion, at the far end of which nectar is secreted. The five stamens and the pistil project from the mouth of the tube. The newly opened flower is almost white, while the style of the pistil bends downwards; but the stamens stand out stiffly. In its later stage the flower becomes yellow, its exhausted stamens bend down, while the style of the pistil rises up and lengthens, so that the stigma is brought into the position originally occupied by the anthers. The flowers exhale a strong scent, especially in the evening, and are visited chiefly by hawk-moths. When a moth hovers in front of a flower in the first stage, it is unlikely to touch the stigma, but is almost certain to get dusted with pollen as it thrusts its proboscis into the tube to get at the nectar. If it then proceeds to a flower in the second stage, the stigma will come into contact with the region of the insect's body on which the pollen was deposited. Humble-bees also visit honeysuckle, but they effect cross-pollination less neatly than the hawk-moths.

The Indian Nasturtium (*Tropæolum*) has the calyx produced into a long tubular spur, which holds the nectar.

It has sometimes been stated that this flower can only be fertilised by the humming-bird hawk-moth (*Macroglossa stellatarum*), no other European insect having a proboscis long enough to reach the extremity of the spur; but this is incorrect. Though common in the British Islands, the humming-bird hawk-moth is somewhat uncertain in its appearance, and one may keep watch in a garden for days together without seeing one of these insects. But the ubiquitous humble-bees frequently visit Nasturtiums during the summer months, and there can be no doubt that they are largely responsible for the abundance of seed which the plants produce. For the Nasturtium is self-sterile—*i.e.* incapable of effecting the pollination of its own stigma. "When it first opens" (writes Lord Avebury) "the anthers are unripe, the pistil is short and immature. Soon, however, one of the anthers ripens, opens, and turns up, so as to stand directly in front of the opening to the tube; a humble-bee, therefore, or other insect of similar size, visiting the flower for the sake of its honey, could not fail to rub some of the pollen off on her breast. Shortly afterwards a second stamen ripens, and assumes the same position, with the same result, and the rest gradually follow. In flowers which I have watched, this process occupies from three to seven days, by which time the stamens have all come to maturity, after which the anthers drop off, and the filaments turn down so as to be well out of the way. It is now the turn of the pistil, which in the meantime has elongated, and assumes the position which the stamens had successively occupied; the result of which is that a bee which had previously visited a younger flower and dusted her breast with pollen could not fail to deposit some of the pollen on the stigma."

The reader will perceive that any increase in the length of the floral tube must tend to restrict the number of

insects capable of extracting nectar from a given blossom. There are many species of hawk-moths with very long sucking-trunks. Except when the insect is feeding, the trunk is coiled up beneath the head; but it can be shot out and inserted into a flower with great rapidity and precision. This may be observed by watching the beautiful elephant hawk-moths as they fly on summer evenings about such blossoms as honeysuckle and rhododendron. Some exotic moths have trunks twice, or even thrice, as long as their own bodies. They visit flowers with exceptionally long and narrow tubes, such as those of the Nicotiana or tobacco. This plant is also typical of many which reserve their flowers exclusively for insects that fly in the twilight or at night. In full sunlight the tobacco flowers are all tightly shut up and look half-dead; but as evening approaches each one unfolds its petals and becomes an alluring star, readily distinguishable at a distance long after the reds and blues and purples of other flowers have faded away in the gloom.

The fact that most night-blooming plants have pale or white flowers corroborates the view that insects can see and appreciate colours. Moreover, the flowers of certain plants are highly coloured and conspicuous in exact proportion to their dependence upon the visits of insects. A striking case in point is that of our wild crane's-bills. The handsome meadow crane's-bill (*Geranium pratense*) has purplish-blue flowers which are nearly twice as large as those of the mountain crane's-bill (*G. pyrenaicum*), which again has much larger flowers than those of the dove's-foot crane's-bill (*G. molle*); while those of *G. pusillum*, which grows commonly on waste ground, are still smaller. Now the meadow crane's-bill, like the rosebay willow-herb, is absolutely dependent upon the visits of insects, because the stigma does not mature until all the

stamens have shed their pollen. The mountain crane's-bill is almost in the same case, but not quite; its stigmatic lobes unfurl while some of the stamens remain upright, and before they have shed all their pollen. Thus self-pollination is possible as a last resort. In the dove's-foot crane's-bill the pistil matures in advance of the second whorl of stamens, and the flower is often self-fertilised; while in *G. pusillum* it matures before any of the stamens, and self-fertilisation is the rule. These facts suggest, as Lord Avebury has said, that "where we find within the limits of one genus some species of flowers which are much more conspicuous than others, we may suspect that they are also more dependent upon the visits of insects." The same observer also proved many years ago that bees, at least, exercise a deliberate choice in the matter of colour, and show a distinct preference for blues and purples; while every field naturalist is aware that most other insects evince a special liking for a particular kind of flower to the exclusion of other kinds. We may therefore liken the brightly coloured petals of flowers to advertisements. They say to the insects: "Here is nectar—here is pollen; come and sample the good things that I hold in keeping." Moreover, it is interesting to notice that the conspicuous blotches or lines of colour upon the petals of flowers generally converge about the opening which gives access to the nectary. Such specialised markings have been appropriately called "honey guides"; and it is significant that they are absent from the petals of night-flowers—where, of course, they would not be visible, and would therefore be superfluous. "I did not realise the importance of these guiding marks" (writes Lord Avebury) "until, by experiments on bees, I saw how much time they lose if honey, which is put out for them, is moved even slightly from its usual place."

Blue Salvia (*Salvia patens*): Flower in first or pollen-shedding stage (to left), the connectives made to descend by means of a straw inserted into the corolla tube. Flower in later stage (to right) with lengthened style

Flower of Violet, showing "honey guides" on lower petals (magnified)

Flower of White Dead-Nettle, from side, showing lip and hood (magnified)

Flower of Indian Nasturtium (*Tropæolum*): side view (to left) showing spur, and front view (to right)

In one sense, at least, a conspicuous flower may be regarded as the creation of countless generations of insects which have come and gone through the ages. For while the colours and perfumes of flowers entice the insect from afar, and direct its passage to the nectary, their varied forms and mechanisms minister to the comfort of the visitor, even as they ensure a ready traffic in pollen. All these marvellous adaptations are the actual outcome of the process itself. The Rev. G. Henslow tells us that "just as a muscle increases with use, so does the protoplasm of plants respond and cause the structure which contains it to adapt itself by growth in various ways to the weights, thrusts, &c., which it receives." Those primitive flowers which responded most successfully to the weight of insects standing upon them transmitted to posterity—not, perhaps, the enhanced stability acquired in their short struggle for supremacy, but the inborn capacity to respond again and again with ever increasing effect. The same principle underlies all the adjustments of flowers to insects, whether of colour, form, or mechanism; while the insects themselves must have been modified reciprocally, though probably in a less degree.

The elaborate adjustment of a flower to a particular insect visitor is almost always accompanied by a reduction in the amount of pollen produced, and a conservation of the nectar from unbidden guests—*i.e.* insects which are unable to effect cross-fertilisation. Flowers such as the wild rose and the poppy, that secrete no nectar, have very numerous stamens which produce large quantities of pollen—doubtless to offset that which the insect visitors devour. Such blooms may be regarded as primitive, at least in so far as their adaptation to insects is concerned. This is apparent when we compare them with a more highly specialised flower, such as the white dead-nettle (*Lamium*

P

album). Here the five petals are united to form a tubular corolla, with a broad lip which serves as an alighting place for insects, and a hood which protects the essential organs. There are only four stamens, the anthers of which lie beneath the hood. The style of the pistil rises between the filaments of the stamens, and ends in a two-lobed stigma. Nectar accumulates in the narrow, basal part of the corolla, and is protected from unbidden guests by a ring of hairs. Humble-bees are the chief visitors. They alight on the lip, and thrust their heads into the neck of the corolla to reach the nectar. In so doing the bee first touches the stigma, which is thus likely to receive pollen brought from another flower, possibly from another plant. A further supply of pollen is deposited by the anthers on the insect's back, and this will be carried to the next flower visited. Since the stigma is receptive when the anthers are shedding their pollen, the flower may readily be self-pollinated through the agency of insects; but because the flowers are frequently visited, and the bees pass rapidly from one to the other, the chance of cross-pollination is very great. A somewhat similar adjustment is seen in the yellow iris, or flag (*Iris pseudacorus*). The three outer leaves of the perianth are large, spreading, and recurved, the three inner ones small and erect. All six join together at their bases to form a short tubular region wherein nectar is secreted. This accumulates round the bases of the styles, and is reached by the insect through minute channels on either side of the stamens. The three styles are petal-like, and arch over the corresponding stamens and outer segments of the perianth, the stigma being a projecting lip on the under surface of the style. Each third of the iris bloom may therefore be likened to an irregular flower. Pollination is mainly effected by humble-bees. In order to reach the nectar, the insect

forces its way into the passage formed by the outer perianth petal and the over-arching style. In so doing its back comes into contact first with the stigmatic lip, which scrapes off any pollen that may have been carried from another bloom; then with the anther of the stamen by which more pollen is deposited. As the bee comes out of the flower its back touches only that part of the stigmatic lip which is unreceptive, so that immediate pollination is impossible. There is nothing to prevent the insect from entering another section of the same flower, or another flower of the same plant; but observation has shown that it more often flies to one at a distance, and thus effects cross-pollination.

In flowers of the sage tribe, the pollinating mechanism has been brought to a marvellous state of perfection. It may be studied most easily in the handsome blue salvia (*Salvia patens*), which is often cultivated in gardens. Like the white dead-nettle, the flower has a broad lip and a hood, but its internal structure is different. Two of the four stamens are abortive. The other two have short filaments, but the connective between the anther lobes is enormously elongated. The lower lobe of each functional anther contains no pollen, but serves with its fellow to block up the entrance to the corolla tube. Thus, when a bee thrusts its head into the tube to search for nectar, it pushes against these abortive anther lobes, causes the long arms of the connectives to descend, and thus brings the pollen-bearing anther lobes into contact with its back. In older flowers that have shed their pollen, the style of the pistil lengthens and bends down so that the receptive stigma grazes the bee's back at the exact spot touched by the anthers of a younger bloom.

Flowers of the pea tribe secure cross-fertilisation by means of a piston apparatus which pumps pollen on to

the visiting insect, as in the well-known bird's-foot trefoil (*Lotus corniculatus*). The corolla consists of five petals. The largest, which stands up at the back of the flower, is called the standard. Below this are two smaller petals, called wings, which overlap two more petals that are united to form a flattened, tubular structure tapering to a point, where the tube is open. This structure, known as the keel, completely encloses the essential organs of the flower. One stamen is free; but the filaments of nine are joined together and form a kind of trough within which lies the ovary. The slender style lies between the free ends of the stamens and extends beyond them, the stigma being actually surrounded by the pollen which is discharged by the anthers into the tip of the keel. It is not receptive, however, until it is rubbed. Nectar is secreted round the base of the ovary, and is accessible only through openings at the base of the free stamen. The flower is visited especially by bees, which alight upon the wings. As these interlock with the keel, the weight of the insect serves to depress the latter, and the rigid stamens expel pollen from the orifice at its tip. The stigma is also forced out, and rubs against the insect's body at the spot where pollen is likely to have been deposited by another flower. Experiment has shown that the pumping mechanism of the bird's-foot trefoil may be worked by an insect eight times in succession before the store of pollen is exhausted.

In the foxglove tribe (*Scrophulariaceæ*) we find very diverse adaptations. The foxglove itself (*Digitalis purpurea*) is exclusively cross-fertilised by humble-bees, which alone are large enough to fill the tunnel-like tube of the flower. Insects which are too small to touch the anthers are kept at bay by a palisade of hairs across the mouth of the corolla. Self-pollination is possible, how-

ever, if the visits of humble-bees are delayed or prevented. Lord Avebury has likened the well-known snapdragon to "a strong box of which the humble-bee only has the key." The flower resembles the foxglove in its general plan, but the lower lip of the corolla is pressed closely against the upper lip, so that small insects are quite unable to force an entrance. But the burly humble-bee's superior strength enables it to force its head and shoulders between the jaws of the flower, and to gather nectar. In so doing it gets dusted on the back with pollen, and flies away to effect the cross-pollination of the next snapdragon which it visits. In the well-known monkey musk (*Mimulus luteus*) the bilobed stigma exhibits a remarkable sensitiveness. When irritated, as by the touch of a bee entering a flower, the lobes of the stigma immediately close together like the leaves of a book; thus, when the insect subsequently backs out, there is no risk of immediate pollination. The stigma remains closed after stimulation for several minutes, when it re-opens. "This repeated opening of the stigma," writes Kerner, "is very important in case the first insect visiting the flower should have brought no pollen with it. Since the stigma opens again, it has apparently some expectation of a second visit. Should this also be unsuccessful it may open a third time. The opening and closing usually continue until at length an insect deposits pollen on the stigma. When this happens the stigma, though opening yet again for a brief period, remains permanently closed so soon as the influence of the pollen is felt." The flowers of the germander speedwell (*Veronica chamædrys*) have very short corolla tubes, from which the nectar can easily be sipped; but there is no alighting platform. They are especially visited by small Diptera of various kinds. The method by which cross-pollination is effected is described

by Mr. W. H. Lang in the following passage: "If, as is usually the case, the fly approaches the flower on the wing immediately in front, the first part of the flower to come in contact with the lower surface of its body will be the stigma. Alighting on the flower, the insect may be seen, in trying to gain a foothold, to grasp the bases of the stamens and to draw them together with its legs, thus rubbing the anthers against the under surface of its body. This region will, after visiting a flower, be dusted with pollen, and on the insect going to another flower the stigma will receive some of this. If the position of the various parts in the opening flower is taken into account, it will be readily understood that the pollen would not be likely without insect agency to get from the anthers, borne to either side on long stalks, to the stigma, projecting in the middle line in front. The whole apparatus is, however, suited for cross-pollination by the help of small flies, and the way in which it works can be verified by careful observation of a group of the plants on a sunny day. The reduction in number of the stamens to two is an indication of the precision of the method of pollination." Lastly, in the figwort (*Scrophularia*) we have a flower which caters especially for wasps, and is almost exclusively cross-pollinated by these insects. The corolla tube is short and swollen. The stamens are four, but the fifth is represented by a petaloid scale which occasionally resumes the functions of an anther. Two large drops of nectar are secreted and lie at the base of the corolla, while the flower exhales a faint, carrion-like odour. The stigma matures first. Later, the stamens become erect and shed their pollen. To get at the nectar, the wasp crawls over the lip of the corolla, and, in the case of the older flower, gets dusted with pollen on the under part of its body. If it subsequently visits a flower in the

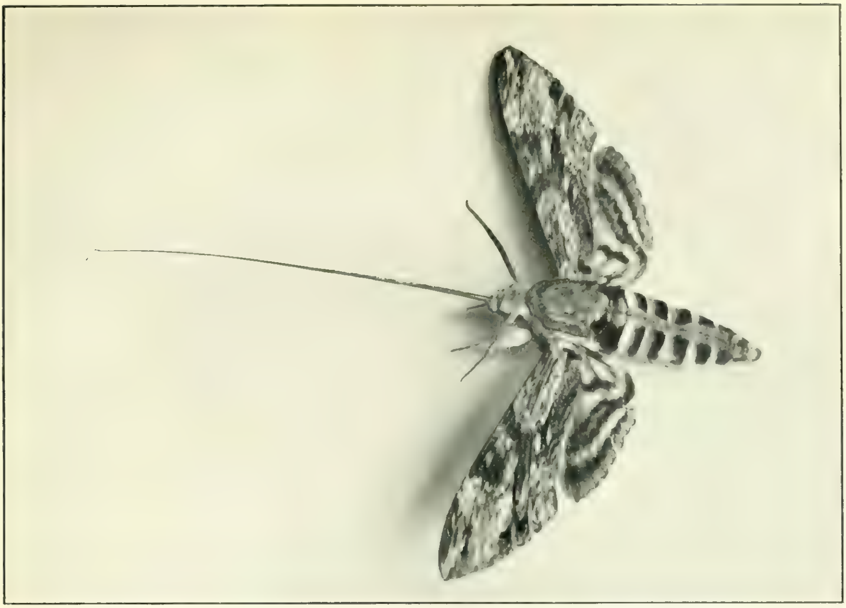
younger stage, the stigma comes into contact with the same part of the insect's body and cross-pollination results. The style of the pistil bends down after pollination; but if this should not take place, owing to no insect having visited the flower, it remains erect until the anthers shed their pollen upon the stigma. In the early stage of the flower, therefore, the conditions favour cross-pollination; in the later stage, self-pollination is still possible.

The fact that the figwort blooms exhale an unpleasant odour lends support to our belief that the scents of flowers are appreciated by insects. Wasps, as everyone knows, have a liking for strong meats, although they consume a certain amount of sweet food as well. When they visit the figwort they are perhaps a little disappointed to find nectar instead of carrion; but they solace themselves with the sugary fluid, and incidentally serve the flower by promoting its cross-fertilisation. We see, therefore, that while the delicate perfumes of many flowers are calculated to charm such insects as butterflies, moths, and bees, the strong odours of others are peculiarly attractive to certain flies and beetles which revel in the products of decay. Many large tropical flowers attract carrion-feeding insects in this way. Both in their coloration ("livid spots, violet streaks, and red-brown veins on a greenish or fawn-coloured background") and in the disgusting odours which they distil, they reproduce the evidences of putrefaction. By such means the huge tropical birthworts (*Aristolochia*) lure flies into their cavernous corollas through a narrow opening beset with hairs directed inwards. Although entrance is easy, immediate return is impossible. The flies are held in durance until the pistil passes maturity and the stamens ripen and shed their pollen. Then the hairs of the tube shrivel up and release the prisoners,

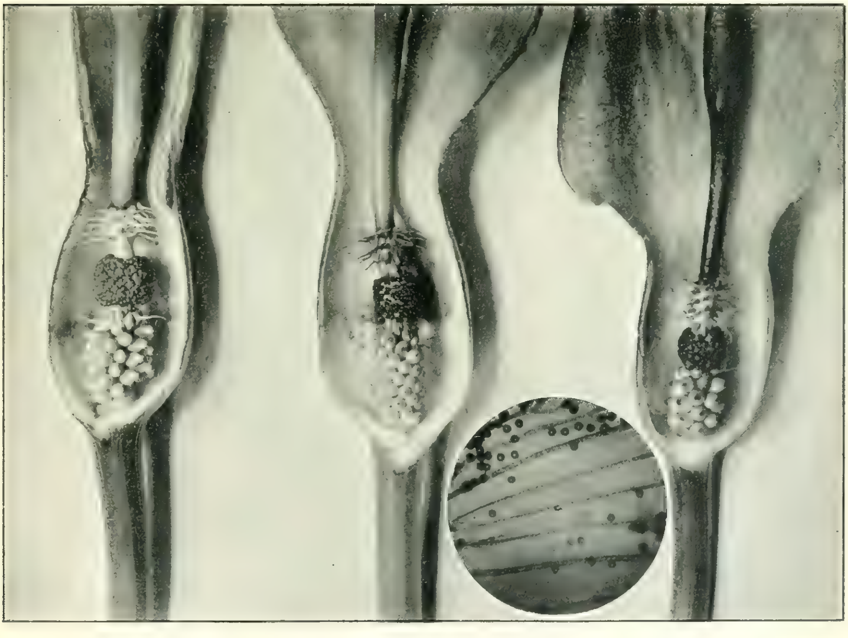
well dusted with pollen, which they carry to another flower.

Very similar is the treatment accorded to its insect visitors by the familiar wild arum, or cuckoo-pint (*Arum maculatum*). The flower spike of this plant, called the spadix, is enveloped by a large sheathing bract, or spathe. The spadix ends in a purple club, and bears the flowers clustered upon its lower part. They comprise abortive, hair-like flowers; anthers or male flowers; and pistils or female flowers—this being the order of their arrangement from above downwards. Insects, especially a small midge known as *Psychoda phalœnoides*, are attracted by the purple club of the spadix and the strong odour of the inflorescence. The hair-like flowers radiate downwards, and allow the insects to creep into, but not to escape from, the chambered portion of the spathe. The female flowers mature first, and receive pollen brought by the insects from another inflorescence. Later, the anthers or male flowers mature, and the midges get dusted with pollen. Finally, the abortive hair-like flowers shrivel up, the spathe begins to wither, and the midges make good their escape. If any of them fly to another arum, they will help to cross-pollinate its female flowers. It is not uncommon to find several hundreds of these tiny midges in the cavity of a single spathe.

In some flowers the pollen is bound up into convenient masses, and these are torn away bodily by the visiting insect and carried to another bloom. Many of the orchids, for instance, are really elaborate contrivances to secure cross-pollination in this way. In our own early purple orchis (*Orchis mascula*) there are six perianth leaves, five of which form a kind of hood over the essential organs; while the sixth is a broad lip, called the labellum, which serves as an alighting platform. The labellum is also continued back-



Convolvulus Hawk-moth (*Sphinx convolvuli*) with proboscis extended



Inflorescences of Wild Arum (*Arum maculatum*) in three successive stages.
(Inset) Pollen grains on wing of Midge (*Psychoda phalænoides*), greatly magnified

wards as a tubular spur. The solitary anther consists of two rather widely separated cells, which are open in front; and each cell contains a pollen-mass, or pollinium, which has a tapering stalk ending below in a round, sticky disc. These discs lie loosely in a cup-shaped envelope called the rostellum, which is easily ruptured. The stamen is confluent with the pistil, and they form together the structure called the "column"—the two receptive areas of the stigma lying just within the opening which leads to the spur. Although no nectar is secreted, Darwin showed that the flower is visited by bees, which are able to obtain a sweet juice by probing the inner walls of the spur. In so doing the insect's head presses against the rostellum, which it ruptures; and when it flies away it carries the pollinia attached by their viscid discs to its head or proboscis. The discs contract unequally in drying, with the result that the pollinia bend forward and diverge slightly from one another. Darwin found that this act of depression is accomplished in the course of thirty seconds on an average. Thus, when the bee visits another flower, the pollinia are in such a position that they are brought into contact with the sticky stigmatic surfaces, and cross-pollination is effected. Other long-spurred orchids, in which the alighting platform is reduced or absent, rely upon the visits of moths, which carry off the pollinia on their sucking-trunks. The species known as *Angræcum sesquipedale*, from Madagascar, has a spur more than eleven inches long, from which Darwin inferred the existence of a hawk-moth with a proboscis equally long—a deduction which subsequently proved to be correct.

Still more remarkable are the contrivances for pollination in certain tropical orchids. We may quote two instances from Darwin's classical work on the subject. The first refers to a species known as *Coryanthes speciosa*.

The flowers are very large, and the labellum, instead of forming a spur, is converted into a bucket, into which liquid drips from two special glandular appendages. This fluid, though slightly sweet, does not deserve to be called nectar; nor does it attract insects — this office being served by fleshy, succulent portions of the labellum itself which certain humble-bees are eager to eat. When the bucket is full, the fluid escapes through a kind of spout, which is over-arched by the column bearing the stigma and pollen-masses. Humble-bees congregate upon the labellum, often in considerable numbers; and in their struggles to get a share of the coveted dainty which the flower provides, some of them fall into the bucket. When a bee gets a ducking it can only escape from its unpleasant predicament by creeping through the overflow spout, and in so doing it must needs pass beneath the column. The first bee to do this gets the pollinia glued to its back. As soon as its wings are dry, it flies to the same or another flower, where sooner or later it gets another wetting, and goes through the whole distressing process of its inglorious exit once again. This time, however, it carries pollen-masses which, as the insect creeps through the spout, come into contact with the stigma. In this way pollination is effected. "There cannot be the least doubt," concludes Darwin, "that the fertilisation of the flower absolutely depends on insects crawling out through the passage formed by the extremity of the labellum and the over-arching column. If the large distal portion of the labellum or bucket had been dry, the bees could easily have escaped by flying away. Therefore we must believe that the fluid is secreted by the appendages in such extraordinary quantity, and is collected in the bucket, not as a palatable attraction for the bees, as these are known to gnaw the labellum, but

for the sake of wetting their wings, and thus compelling them to crawl out through the passage."

The second example relates to orchids of the genus *Catasetum*, in which the pollinia and the stigmatic surfaces are in different flowers, self-pollination being thus out of the question. The pollinia are furnished with viscid discs of huge size, but these are not so placed that they would be likely to touch and adhere to an insect visiting the flower. Indeed, there is nothing in the chambered portion of the flower likely to attract insects. "How then does Nature act?" asks Darwin. "She has endowed these plants with . . . the remarkable power of forcibly ejecting their pollinia even to a considerable distance. Hence, when certain definite points of the flower are touched by an insect, the pollinia are shot forth like an arrow, not barbed however, but having a blunt and excessively adhesive point. The insect, disturbed by so sharp a blow, or after having eaten its fill, flies sooner or later away to a female plant, and, whilst standing in the same position as before, the pollen-bearing end of the arrow is inserted into the stigmatic cavity, and a mass of pollen is left on its viscid surface. Thus, and thus alone, can the five species of *Catasetum* which I have examined be fertilised." Small wonder that Darwin should have regarded these flowers as "the most remarkable of all orchids."

Like the flowers of the orchids, those of the so-called milkweeds (*Asclepiadaceæ*) of the New World are wonderfully designed with reference to cross-pollination by insects; but in these cases the flowers are regular. Professor J. W. Folsom gives the following account of the manner in which cross-pollination is effected: "As a honey-bee or other insect crawls over the flowers to get at the nectar, its legs slip in between the peculiar nectari-

ferous hoods situated in front of each anther. As a leg is drawn upward one of its claws, hairs, or spines frequently catches in a V-shaped fissure and is guided along a slit to a notched disc, or corpuscle. This disc clings to the leg of the insect, which carries off by means of the disc a pair of pollen-masses or pollinia. When first removed from their enclosing pockets, or anthers, these thin spatulate pollinia lie each pair in the same plane, but in a few minutes the pollinia twist on their stalks and come face to face in such a way that one of them can be easily introduced into the stigmatic chamber of a new flower visited by the insect. Then the struggles of the insect ordinarily break the stem, or retinaculum, of the pollinium and free the insect. Often, however, the insect loses a leg or else is permanently entrapped, particularly in the case of such large-flowered milkweeds as *Asclepias cornuti,* which often captures bees, flies, and moths of considerable size." In this way certain Asclepiads, especially those which are cultivated in regions to which they are not indigenous, have come to be called "cruel plants." It has been truly said, however, that Nature's broad methods are not exempt from occasional contretemps. When these flowers are visited by powerful insects, such as large humble-bees or wasps, the plan works to perfection; but when the mechanism is tampered with by weaklings, they have to pay the penalty of their rashness.

There is one point connected with the pollination of flowers that we must not overlook, namely, that certain insects, attracted in the first instance by the promise of nectar, remain to lay their eggs either upon or close to the flower. This is the case, for example, with night-flying moths of the genus *Dianthœcia*, the caterpillars of which feed within the seed-capsules of the well-known red and white campions—plants of the genus *Silene* and

its allies. When bent on egg-laying, the females have frequently been observed to carry pollen from the anthers of one bloom to the stigma of another; and but for this exchange the plants might be infertile. The reader will perceive, however, that the device is not above criticism, seeing that the young caterpillars are destined to destroy the very seed which their parent has helped to produce. In practice, however, the seeds in a given capsule are seldom all destroyed, while the same plant always bears uninjured capsules which owe their fertility to the visits of male moths, or of females which have exhausted their store of eggs.

The relations which exist between the American yuccas and certain small, white-winged moths of the genus *Pronuba* are even more extraordinary. The facts were first ascertained by Professor C. V. Riley, whose detailed account of the fertilisation of *Yucca filamentosa* by *Pronuba yuccasella* is here summarised. The male moth is not specially remarkable, but the female is fitted for her peculiar duties by modifications which are unique among scale-winged insects. Not only are her maxillary palpi well developed (the reader will remember that in all other moths these organs are either very small or altogether wanting), but she carries in addition a pair of long, prehensile "tentacles" which are without precedent among her kith and kin. She is also equipped with a long protrusible ovipositor which combines in itself the functions of a lance and a saw. She makes her début simultaneously with the blooming of the yucca, and frequents the flowers soon after dark. So intent is she upon her duties that she will continue to work even in the light of a lantern. Clinging to a stamen, she first scrapes off the pollen with her abnormal tentacles. She then raises her head, and commences to shape the precious grains into a little

pellet, using her front legs—"very much as a cat does when cleaning her mouth." After scraping the pollen from one stamen she proceeds to another, and so on until she has formed a ball which is often thrice as large as her own head. This she holds firmly between her tentacles, and usually, though not invariably, flies to the bloom of a neighbouring plant. Here she lays one or more eggs in the ovary of a flower; and after so doing actually climbs up the pistil, thrusts her pellet of pollen into the stigmatic tube, and pushes it firmly home. As a result of this forceful pollination, the ovules develop into seeds, some of which are consumed by the larva, though plenty are left to perpetuate the plant.

Three species of *Pronuba* are known, each being attached to a distinct species of yucca; and Professor Riley's investigations lead him to believe that these plants never set seed in districts where their attendant moths are not found, or when the insects are excluded artificially. The habits of *Pronuba* are all the more wonderful because she herself derives no benefit from what she does. Her proboscis is imperfectly formed, her alimentary canal is practically functionless, and she has never been seen to feed. Doubtless her ancestors did so, and were first attracted to the yucca in search of nectar or pollen; but to-day the actions of the moth are disinterested in the fullest sense of the word. Moreover, we must not assume that the moth consciously performs the act of pollination for the sake of her offspring. The whole procedure is instinctive.

Quite as remarkable, and even more complicated, is the interdependence of fig-trees and certain small gall-wasps. In order to understand this relationship, the reader must be told that a fig is really a hollow inflorescence—a chamber bearing numerous simple flowers on its

inner walls—access to which is gained through a small orifice beset with leafy scales. The male and female elements are borne by separate flowers; while many species of fig have two kinds of female flowers, namely, some with long styles and developed stigmas, and some with short styles and abortive stigmas. The latter are called "gall-flowers" for a reason which will shortly appear. The arrangement of the flowers varies in different species; but in the case of the common fig (*Ficus carica*) of Southern Europe it is this: Some individuals produce inflorescences containing only female flowers, while others produce inflorescences with male flowers near the opening and gall-flowers lower down. The former individuals are known as *Ficus*, the latter as *Caprificus*.

"We have to consider," writes Kerner in his *Natural History of Plants*, "what may be the meaning of the gall-flowers. As the name indicates, not fruits but galls are produced from these modified female flowers, and this happens in the following manner. There is a small wasp belonging to the *Chalcididæ*, . . . *Blastophaga grossorum*, which lives upon the fig cultivated in the south of Europe. This insect passes into the cavity of the inflorescence through the orifice, and there sinks its ovipositor right down the style-canal of a flower, and deposits an egg close to the nucellus of the ovule. The white larva developed from the egg increases rapidly in size and soon fills the entire ovary, whilst the ovule perishes. The ovary has now become a gall. When the wasps are mature they forsake the galls. The wingless males are the first to emerge, and they effect their escape through a hole which they bite in the gall. The females remain a little longer in their galls, and are there fertilised by the males. Afterwards they come out also, but only stay a short time within the cavity of the inflorescence, issuing from it

as soon as possible to the open air. They accordingly crawl up to the mouth of the inflorescence, and in so doing they come into contact with the pollen of the male flowers and get dusted all over the body—head, thorax, abdomen, legs, and wings. After squeezing through between the scaly leaves at the mouth of the inflorescence, and having at last reached the outside, they let their wings dry and then run off to other inflorescences on the same or a neighbouring fig-tree. I say 'run' advisedly, for they but rarely make any use of their wings in this act of locomotion. They now seek exclusively inflorescences which are in an earlier stage of development that they may lay their eggs in the ovaries. Having found such an one they crawl to the opening and slip between the scales into the interior. Sometimes their wings are injured in the act of entering; indeed, the wings are occasionally broken off altogether, and are left sticking between the scales near the aperture. Once inside the inflorescence, the wasps immediately devote themselves to laying eggs, and in the process are of necessity brought into contact with the stigmas of female flowers. The wasps are still powdered over with the pollen from their birthplace, and it is now brushed off on to the stigmas of the female flowers, which are thus pollinated from another inflorescence. If the pollen is deposited on normal pistilliferous flowers the latter are able to develop seeds endowed with the power of germination; if it falls on gall-flowers it is, as a rule, ineffectual, because the stigmas are more or less abortive. Moreover, no seeds are formed in these gall-flowers, owing to the eggs of the wasp being laid in their place. In those species of fig in which gall-flowers are not specially provided, the eggs are laid in a certain proportion of the normally developed female flowers. It

has, however, been observed in the case of the common fig (*Ficus carica*) that eggs of *Blastophaga grossorum* laid in ordinary female flowers do not come to maturity, or, in other words, that a normal female flower is not converted into a gall, even if the wasp in question sinks its ovipositor into it and deposits an egg in the interior. For the style of the normal female flower of *Ficus carica* is so long relatively to the ovipositor of *Blastophaga grossorum* that the egg cannot be inserted quite into the ovary, but is left at a spot which is not favourable to its further development, and there perishes. The gall-flowers of this species of fig, with their short styles, are, on the other hand, pre-eminently adapted to the reception of the egg at the spot where the ovule would otherwise develop, while at the same time they are not adapted to the production of seeds capable of germination, since no pollen-tubes can develop upon their abortive stigmas. Evidently we have here a case of complementary functions or division of labour in accordance with the following plan. The wasps which deposit their eggs in the figs carry the pollen both to the short-styled gall-flowers and to the long-styled ordinary female flowers, and attempt to lay their eggs in both kinds of flower. The gall-flowers are prepared expressly for the reception of the wasps' eggs, and young wasps actually develop in them; but their stigmas not being adapted to the reception of pollen, they do not promote the growth of pollen-tubes, and no fertile seeds are produced. On the other hand, pollen-tubes develop on the stigmas of the long-styled flowers, and the latter produce fertile seeds; but the long style prevents the proper placing of the wasps' eggs, and consequently galls are never or very seldom produced in connection with these flowers."

The phenomenon of cross-pollination by insects is

vested with a kind of glamour which inevitably casts its spell over the mind. Staid men of science have experienced this enchantment, and there can be little doubt that their judgment has been occasionally influenced thereby. They have observed that plants which are habitually self-fertilised are often small weeds and annuals, and that their flowers are usually insignificant when compared with those which are frequently visited by insects. These facts have prompted the assumption that there is something infelicitous in self-fertilisation, and that plants which have been able to secure an interchange of pollen have climbed, as it were, out of the ruck to their abiding advantage. But this is only one aspect of the question; for botanists tell us that self-fertilised plants invariably set an extraordinary abundance of good seed, that they tend to monopolise the soil, and that they are more widely distributed on the face of the earth than any others; whereas those plants which depend solely upon the chance visits of insects are relative failures in the struggle for existence. Indeed, it is said that whereas cross-fertilisation is at first a stimulating process, resulting in the production of "fine" plants in the popular sense of the word, its long continuance tends to reduce fertility almost to zero. This is made manifest in the case of the orchids, most of which cannot set seed at all unless they are visited by the right kind of insect. The Rev. G. Henslow mentions a tropical orchis (*Dendrobium speciosum*), growing in the open in its native country, which bore 40,000 blossoms but produced only one pod.

These facts seem at first to hint at a flaw in Nature's scheme. But we must remember that "evolution is no mechanical tendency making for perfection; it is simply the continual adaptation of plastic life, for good or evil, to

the circumstances that surround it." Moreover, the chief factors which have influenced the evolution of highly specialised flowers are not "natural" in the strict sense of the term. For just as mankind, by a system of artificial selection, or "breeding," has established races of domestic animals in accordance with his needs or fancies, so insects have left their mark upon the flowers. In a word, natural selection has been superseded in large measure by the intrusions of the insect; and while we may admire the elaborate mechanisms whereby the increase of the plants is maintained in face of incalculable odds, we can hardly extol them as the best conceivable. Indeed, such flowers as orchids must probably be regarded as the outcome of profitless variations controlled by the circumstances of the hour—in other words, by the visitations of insects. The insects have gained much in nectar, but the fruitfulness of the plants has steadily declined. It is interesting to notice that a few flowers seem to be escaping from this downhill progress. Our English bee-orchis (*Ophrys apifera*), though obviously designed to attract insects, is seldom or never visited. This lack of attention would involve other orchids in sterility. But in the bee-orchis the anther cells open soon after the flower is fully expanded, allowing the pollinia to fall out, the viscid discs still remaining in the rostellum. In this position the slightest movement of the flower—such as might be caused, for example, by a breath of air—sets the elastic caudicles vibrating, and the pollinia almost immediately strike the stigma. In this way self-pollination is effected. Thus, while many orchids that depend solely upon the visits of insects remain barren, the bee-orchis apparently produces as many seed-capsules as flowers.

CHAPTER XIV

THE ENEMIES OF INSECTS

PROBABLY the most baneful enemies of insects are found among their own kith and kin, for the number of predaceous species and parasites is very great. But when we realise that something like four-fifths of all existing land animals are insects, we are not surprised to learn that they are assailed by many creatures other than members of their own class. Whole groups of animals, from mammals downward, find in insects their chief—often their only—source of food. In Britain, the mole, the shrews, and the hedgehog depend largely upon an insect dietary, the mole doing good service to agriculturists by destroying immense numbers of grubs and caterpillars which harbour in the soil; while our native bats war against nocturnal insects, which they capture on the wing. Abroad, we find many mammals whose structure and habits are profoundly modified to fit them for an insectivorous career. For instance, the great ant-eater of South America is toothless, and has a long, mobile tongue which is kept constantly sticky by the secretions of large salivary glands. With this organ it sweeps up ants and other insects after breaking into their habitations by means of its powerful claws.

Lizards feed largely upon insects. Most of them are extremely agile and hunt their prey. But the interesting chameleons lurk motionless among the branches of trees and shrubs, and dart out their long, sticky tongues to seize such insects as may chance to settle within reach.

These sticky tongues, indeed, are possessed by numerous insectivorous creatures widely separated in the scale of animal life. The woodpeckers have them, so too have the frogs and toads. Our common toad has a trick, exasperating to bee-keepers, of stationing itself near the alighting platform of a hive, and flicking up the busy inmates as they fly past. It is one of the few animals that are indifferent to the bee's sting.

The most consistently insectivorous groups, however, are the birds and the fresh-water fishes; and from an economic standpoint birds must be given the first place, for they are the chief destroyers of agricultural pests in all parts of the world. This subject has been carefully studied, especially in the United States; and it is probable that about two-thirds of the food consumed by birds in a given district consists of insects. Moreover, wherever any kind of insect pest is in the ascendant, birds rally to the spot in abnormal numbers in order to avail themselves of the feast. This fact is well illustrated by the following case which was investigated by Dr. S. A. Forbes. An Illinois apple orchard was being ravaged by "canker-worm" —*i.e.* a species of looper caterpillar allied to that of our March moth (*Anisopteryx æscularia*). It was visited by an extraordinary number and variety of birds, specimens of which were shot in order that the contents of their crops might be examined. "Birds of the most varied character and habits, migrant and resident, of all sizes, from the tiny wren to the blue-jay, birds of the forest, garden and meadow, those of arboreal and those of terrestrial habits, were certainly either attracted or detained here by the bountiful supply of insect food, and were feeding freely upon the species most abundant. That thirty-five per cent. of the food of all the birds congregated in this orchard should have consisted of a single species

of insect is a fact so extraordinary that its meaning cannot be mistaken. Whatever power the birds of this vicinity possessed as checks upon destructive irruptions of insect life was being largely exerted here to restore the broken balance of organic nature."

It is well known that many English birds feed upon insects. The titmice are especially useful, as they destroy many crop pests in all their stages, and during the winter clear off an enormous number of eggs and hibernating insects. Swallows and martins capture myriads of flying insects, including the large "daddy-longlegs" or crane-flies (*Tipula*). They have also been seen feeding upon aphides at the time of their migration from the hop gardens to their winter quarters on neighbouring plum and damson trees. Nearly all the migrants, indeed, are exclusively insectivorous. Among larger birds, the starling and the green plover or lapwing wage a ceaseless war upon many kinds of grubs and caterpillars which infest crops and grass; the kestrel, although the bulk of its food consists of mice, consumes large numbers of beetles, especially cockchafers; while the latter insects, together with night-flying moths, form the staple diet of the night-jar or "fern-owl"—a very useful bird which, in the past, has been subjected to much unwarrantable persecution by ignorant, gun-carrying humanity.

The food of adult fresh-water fishes has been investigated in America by Dr. Forbes, who states that no less than forty per cent. of the total supply is drawn from the insect world. The principal insectivorous fishes are the smaller species. The food of a little minnow (*Phenacobius*), for example, consists of insects to the extent of ninety-eight per cent.—mostly the minute larvæ of certain gnats and midges. The latter are also consumed in enormous numbers by many other fishes; while the larvæ of may-

flies, and those of numerous Neuropterous species, are also important food-items. The larvæ of aquatic beetles, the nymphs of dragon-flies, and the case-making caddis-worms are more rarely molested; while adult water-beetles and bugs appear to be almost exempt from attack.

The foregoing paragraphs must be regarded as the briefest possible outline of a very vast subject. They serve, however, to emphasize the fact that insects are preyed upon by myriads of creatures, great and small. In passing, it is interesting to note that those who have made the food of animals their special study are agreed, in the main, as to the efficacy of the various protective adaptations of insects. With the exception of cuckoos, few birds destroy hairy caterpillars; and although certain birds, reptiles, and amphibians have acquired the knack of feeding upon stinging Hymenoptera, these are sedulously avoided by insectivorous creatures in general. The same remark applies to those insects which emit disagreeable odours and juices.

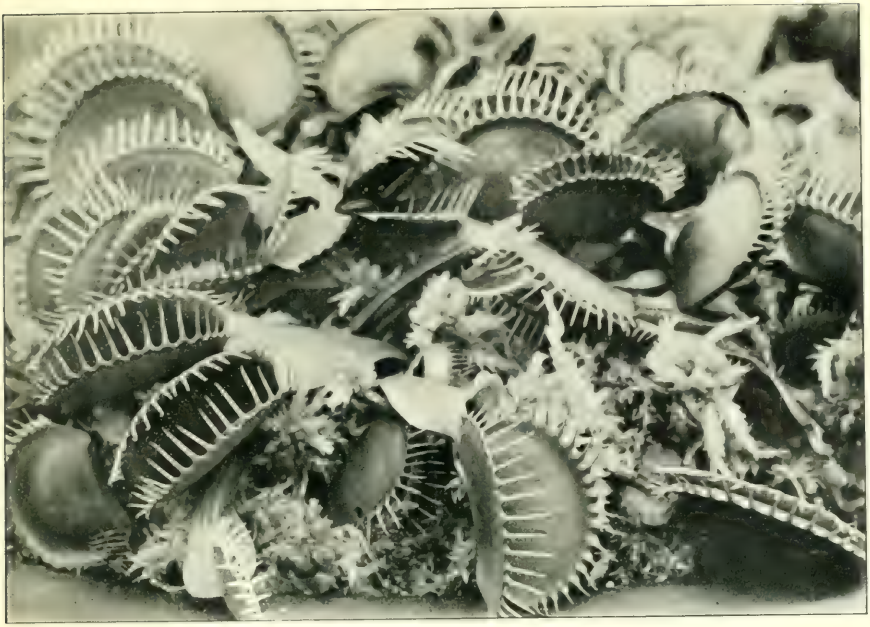
But there are certain enemies against which insects are entirely defenceless. These are the so-called insectivorous plants, of which some five hundred species are known. Most of them grow in boggy or arid soils, poor in nitrogenous substances, and it is believed that this deficiency has forced the plants to embark upon their murderous enterprises. These plant-enemies of insects capture their prey by a variety of contrivances. Among the pitcher-plants the leaf, or the leaf-stalk, takes the form of a hollow vessel which has been aptly described as a combination of lure, pitfall, and stomach. The inner walls are either intensely slippery, or else beset with minute, downward-pointing hairs—devices which favour the ingress of a victim, but effectually prevent its escape. The lower part of the pitcher is charged with liquid, which

may be in part rain-water, but is largely the secretion of special gland-cells. When insects or other small creatures fall into this bath they are drowned, and their soft tissues are slowly digested and absorbed by the plant.

That these death-traps have a flower-like appearance, being daintily coloured and marked with "honey guides," and that they secrete a copious nectar from the parts surrounding their apertures, are among the most astonishing facts of life. Insects are completely deceived by the resemblance and creep into the pitchers, or fly to them from a distance, with the same alacrity that they display in their intercourse with flowers. They feast upon the nectar, then wander or slip downwards until they reach the water. Winged species often make desperate efforts to extricate themselves by flight; but they buffet against the sides of the pitcher, or knock against the lid-like leaf above the aperture, until they are exhausted. They seldom make good their escape.

The true pitcher-plants of the genera *Nepenthes*, *Sarracenia*, and their allies, are tropical or sub-tropical; but we have in Britain an interesting water-plant, the bladderwort (*Utricularia*), which captures its prey in a somewhat similar manner. In this case the traps are little bladder-like structures, the orifices of which are closed by valves so contrived that tiny aquatic animals can enter, but not return. Why these creatures press through the fatal door has not yet been fully explained; but it is a fact that each bladder usually contains a little crowd of prisoners, which slowly perish and become food for the plant. The majority of the victims are minute crustaceans—"water fleas" and the like; but a considerable number are gnat larvæ and other small insects.

The leaves of the butterwort (*Pinguicula*) are sticky, so that small insects settling thereon are held fast. After a



The Venus's Fly-trap (*Dionæa muscipula*)

Fly caught by leaf of Sundew (*Drosera*): greatly magnified

capture the edges of the leaf curl slowly inwards and a peptic secretion is poured forth, the nitrogenous substance of the victim being thus slowly dissolved and absorbed by the plant. Similar digestive arrangements exist in the sundews (*Drosera*), but in these instances the contrivances for trapping the prey are much more perfect. The leaves are studded with numerous red hairs or tentacles, each terminating in a bright drop of sticky fluid. This glistening array is very attractive to insects. When one settles upon a leaf it is held fast. The red hairs bend slowly over, carrying the victim to the centre of the leaf, where it is drenched with digestive ferment. An American observer, Mrs. Mary Treat, writing of the United States sundew, says: "I had supposed it caught only small insects, but . . . I was mistaken; great *Asilus* flies were held firm prisoners; innumerable moths and butterflies, many of them two inches across, were alike held captive until they died—the bright flowers and brilliant glistening dew luring them on to sure death. But what is the use of this wholesale destruction of insect life? Can the plants use them? Upon examination, I find that after the death of the larger insects they fall around the roots of the plants and so fertilise them, but the smaller flies remain sticking to the leaves." Mrs. Treat also discovered that a sundew leaf will bend over and seize an insect pinioned half-an-inch away—a fact which the present writer has himself verified by experiment.

The most remarkable of all insectivorous plants is the Venus's fly-trap (*Dionæa muscipula*) of North America. Darwin referred to it as "one of the most wonderful plants in the world." Each leaf consists of two parts, namely, a flat stalk with leafy expansions on each side, and a bilobed blade bordered with curved spines. On each lobe there are three delicate, almost invisible bristles.

Normally, the mature blade, or "trap," lies flat, or nearly so, and is more or less continuous with the stalk; but if an insect ventures upon it and comes into contact with one of the sensitive bristles, the two lobes spring together with considerable force, and the intruder is imprisoned beneath the interlocking marginal spines. The whole contrivance reminds one of an iron gin or rat-trap. Darwin found that each leaf is able to capture and digest two, or perhaps three, insects in succession; but not more. It then withers, and its place is taken by a younger leaf.

Insects are also killed by fungi. In the autumn, dead house-flies may often be seen sticking to walls and window-panes. Their bodies are greatly swollen, and are surrounded by a quantity of white powder. Such insects are the victims of *Empusa muscæ*—a fungus which attacks flies of various kinds. All the internal organs are gradually invaded and destroyed; and when death results the minute spores of the fungus (the white powder) are ejected in all directions. They are capable of infecting other flies; but how this is accomplished, and in what manner the *Empusa* is carried on from one season to the next, are points which are at present uncertain.

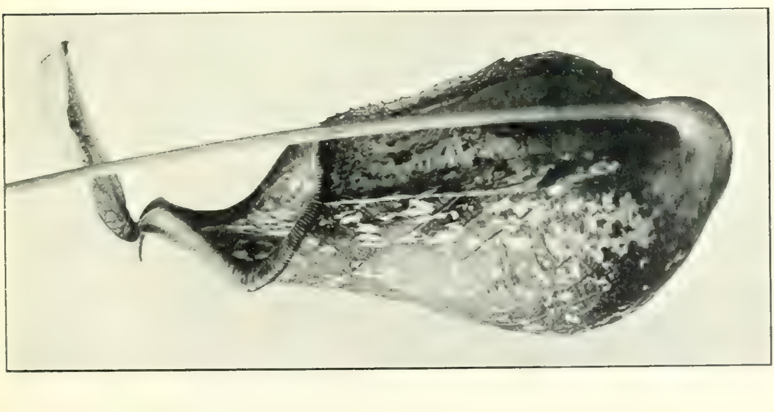
Other species of *Empusa* are known, one of which (*E. aphidis*) infests aphides, and exercises an important check upon their increase. Another (*E. grylli*) attacks grasshoppers and crickets; while *E. aulicæ* occasionally causes a high rate of mortality among caterpillars.

The remarkable objects known as "vegetable caterpillars" are the burrowing larvæ of large swift-moths (*Hepialidæ*) from Australia and New Zealand, which have been done to death by fungi belonging to the genus *Cordyceps*. The fungus first replaces every part of the insect's body, and then sends up a long fructifying shoot through the soil. The caterpillar of our own garden

PLATE XXXVII

A "Vegetable Caterpillar"

House-fly destroyed by a Fungus (*Empusa muscæ*): greatly magnified



Pitcher of a *Nepenthes*

swift-moth (*Hepialus lupulinus*) are similarly afflicted by *Cordyceps entomorhiza*, while allied fungi destroy larvæ, pupæ, and imagines of many kinds. One causes the silk-worm disease known as "muscardine." In France and Germany attempts have been made to utilise some of these fungi for the destruction of pest-insects, such as the grubs of chafer beetles. It is doubtful, however, whether this method could be employed satisfactorily on a large scale.

Bacteria cause epidemic diseases among insects, the most serious from an economic standpoint being the "flacherie" of silk-worms and the "foul brood" of hive-bees.

CHAPTER XV

THE COURTSHIP OF INSECTS

THAT courtship is a recognised institution among insects cannot be doubted. In the following passage Lord Avebury quaintly describes the love-making of a tiny creature known as *Smynthurus luteus*—one of the lowly Apterous insects. "The male, which is much smaller than the female, runs round her, and they butt one another, standing face to face, and moving backwards and forwards like two playful lambs. Then the female pretends to run away, and the male runs after her with a queer appearance of anger, gets in front and stands facing her again; then she turns coyly round, but he, quicker and more active, scuttles round too, and seems to whip her with his antennæ; then for a bit they stand face to face, play with their antennæ, and seem to be all in all to one another."

The sexes of many insects differ not only in size, but in many details of form and colour; and the male is usually the more highly developed, being equipped with elaborate sense-organs and other specialised endowments. For example, his eyes are often very large and prominent. We have already seen that the compound eyes of certain male may-flies are divided, so that the insect appears to have two eyes on each side of the head. Careful examination of these remarkable structures has led to the conclusion that their special function is to discern moving objects in the dusk, thus enabling the insects to secure partners during their brief twilight dances. Large eyes are also a distinctive masculine feature in many species

of bees and two-winged flies, the visual organs often occupying the greater part of the head-area; and in all such cases the male relies chiefly upon his enhanced powers of vision in order to discover his mate.

Certain nocturnal beetles emit a phosphorescent light, our own glow-worm (*Lampyris noctiluca*) being a familiar example. The female glow-worm is wingless, and differs little from the larva in appearance; but her light is infinitely more powerful than that of the winged, large-eyed male. Thus there is reason for thinking that the female's light attracts the male from a distance. These conditions do not always obtain, however, for in some species, such as the fire-flies (*Luciola*) of Southern Europe, the males are more luminous than the females, and are accustomed to form aerial bachelor parties on calm, warm nights. Myriads of them may sometimes be seen moving and sparkling in the darkness; and Dr. Sharp suggests that their lights may "serve as an amusement, or as an incitement to rivalry"; while we are free to believe that the most brilliant suitors find special favour in the eyes of the stay-at-home females.

That the choice of the female is often the decisive factor in insect courtship is admitted by many naturalists. When dealing with the senses of insects we saw that certain male moths can track down individuals of the other sex by scent alone; yet the first male to arrive does not always become the accepted mate. The courtship of the antler moth (*Charæas graminis*) has been well described by Professor Poulton. He tells us how the males assemble from far and near round a freshly emerged female. The suitors buzz in an excited crowd about the object of their passion. Suddenly one is accepted, and all the others immediately disperse. "In these cases the males do not fight or struggle in any way, and as one watches the

ceremony the wonder arises as to how the moment is determined, and why the pairing did not take place before. All the males are evidently most eager to pair, and yet when pairing takes place no opposition is offered by the other males to the successful suitor. Proximity does not decide the point, for long beforehand the males often alight close to the female and brush against her with fluttering wings. In watching this wonderful and complicated courtship one is driven to the conclusion that the female must signify her intention in some way unknown to us, and that it is a point of honour with the males to abide by her decision."

Reference has already been made to the fact that many insects produce scents. These may be divided into two classes, viz. (1) repulsive or protective scents, usually common to both sexes, but often stronger in the female, and (2) alluring scents, which are generally confined to one sex only. The first class has already been dealt with in connection with warning coloration, but alluring scents are germane to our present subject. It has long been known that the males of certain butterflies exhale an agreeable perfume. Thus, the scent of the male green-veined white (*Pieris napi*) has been compared to lemon verbena, that of the small white (*P. rapæ*) to sweet-briar. These odours emanate from the wings, and are produced by curiously shaped scales that arise from glandular cells, by which a volatile fluid is secreted. Similar scales are found on the wings of many other butterflies and moths, and are confined to the male sex. In some species they are scattered among the ordinary scales, in others they are arranged in brand-like patches, or are hidden in a little pouch or beneath a fold of the wing; and there can be little doubt that they are employed in courtship as a means of attraction. This suggestion was first made by

Dr. Fritz Müller as long ago as 1876; and he subsequently convinced himself by actual observation of butterflies in Brazil that his surmise was correct. It is hardly necessary to add that the alluring perfumes of insects can rarely be detected by mankind, but so far as we are able to perceive them they are pleasing, and suggest the faint fragrance of flowers. This agreement between our own æsthetic preferences and those of a butterfly has sometimes been made a subject for wonder; yet there is really nothing extraordinary in the fact that insects, which take their cue from flowers, should be enticed by the flower-like odours of their mates.

Many insects apprise one another of their whereabouts by producing sounds. Cicadas are the most noisy of all insects. The males of a Brazilian species produce a shrill note which is said to equal in volume the whistle of a locomotive. Even Xenarchus, the Greek poet, was aware that the male alone possesses this musical faculty, for he remarks with thinly veiled sarcasm: "Happy the cicadas live, since they all have voiceless wives." There is reason for thinking that male cicadas sing in rivalry, while it can scarcely be doubted that their orchestral efforts excite and charm the females. That this is actually the case with crickets has been proved. Bates, speaking of the field cricket (*Gryllus campestris*), says: "The male has been observed to place itself, in the evening, at the entrance of its burrow, and stridulate until a female approaches, when the louder notes are succeeded by a more subdued tone, whilst the successful musician caresses with his antennæ the mate he has won." Similar observations have been made in the case of the mole cricket (*Gryllotalpa vulgaris*); and Mr. W. H. Harrington says of a common American field cricket that "while the male is energetically shuffling together his wings, raised almost vertically,

the female may be seen standing just behind him, and with her head applied to the base of the wings, evidently eager to get the full benefit of every note produced."

The males of many insects, especially butterflies, are often more strikingly coloured—more "beautiful" in the commonly accepted sense of the word—than the females. The male chalk-hill blue butterfly (*Polyommatus corydon*) has exquisite azure wings, those of the female being dark brown; the male orange-tip butterfly (*Euchloë cardamines*) is adorned with conspicuous orange spots which are absent from the wings of his mate; while among exotic insects we find still more striking examples of masculine splendour yoked to feminine dowdiness. The cause and significance of such sex-difference remains a vexed question among naturalists. Some believe that the male is more showy than his mate because his stock of surplus vitality is greater than hers. In the language of science: "The small and active sperm-cell, with a more abundant vitality than the passive egg-cell, dissipates energy while the egg-cell stores it up." Others, who follow Darwin, believe that the colours and ornaments of male animals are the outcome of sexual selection; that the females, through countless generations, have consistently chosen the most ornate from among their suitors, and have thus transmitted their qualities to posterity. The reason why the female is slow to acquire the characters which she appreciates in the opposite sex is explained on the ground that her need for protection is more urgent. As a rule, she is less alert than the male, and when engaged in egg-laying is exposed to risks from which he is exempt. Thus, while the female occasionally participates in the growing adornment of her species, such a tendency is usually checked by natural selection, which in each generation preserves the best-protected individuals for the office of parentage. The male's greater wariness

and agility—qualities which are indubitably associated with his superior sense-organs and well-balanced physique —are thought to offset any special dangers which his bright colours may entail. Moreover, it is noteworthy that those colours which are believed to play a part in courtship are generally concealed at other times. The male orange-tip butterfly, when at rest with folded wings, is not less perfectly disguised than his mate.

The theory of sexual selection, as opposed to that of exuberant vitality on the part of the male, is certainly the more romantic; while the two are not necessarily Irreconcilable. The essential natures of the sexes must always obtain, and might well constitute the foundation upon which specialised characters, due either directly or indirectly to the choice of the female, could be based. The supposed inadequacy of the insect's æsthetic sense is often urged as a weighty objection. But on this point we can judge only by analogy. If, as we are justified in believing, the chirping of crickets, and the other sounds produced by insects at the period of courtship, are the outcome of sexual selection, why should we assume that decorative colours were evoked in some other manner? "Why" (writes Professor Weismann) "should the eye be less sensitive to specifically male colours and other visible signs enticing to the female than the olfactory sense to specifically male odours, or the sense of hearing to specifically male sounds? . . . decorative colouring and sweet-scentedness may replace one another in Lepidoptera as well as in flowers, for just as some modestly coloured flowers (mignonette and violet) have often a strong perfume, while strikingly coloured ones are sometimes quite devoid of fragrance, so we find that the most beautifully and gaily coloured of our native Lepidoptera, the species of *Vanessa* (the 'tortoiseshells' and their

allies), have no scent-scales, while these are often markedly developed in grey nocturnal Lepidoptera. Both attractions may, however, be combined in butterflies, just as in flowers."

It is a significant fact that the males of certain moths whose females are greatly simplified—their eyes, among other parts, having undergone retrogressive changes—are usually dingy and unattractive. In these cases bright colours would obviously be superfluous, as success in courtship must depend chiefly upon the suitor's speed and keenness of scent. Indeed, the conditions of courtship vary greatly, even among closely related species. Thus, in Britain we have five kinds of swift moths (*Hepialus*). In three instances the males court the females in the usual way, searching for them among the grass and herbage where they lie hidden. But the males of the gold swift (*H. hectus*) and the ghost swift (*H. humuli*) are both provided with dense tufts of scent hairs on the tibial joints of the hind-legs, and these tufts emit a strong perfume, compared to pine-apple, which proves an irresistible attraction to the females. They give chase to the males, and literally buffet them into matrimony. Moreover, among some butterflies the common rule of courtship is reversed, the females being far more ardent than the males. This is the case with our three common white butterflies. In such instances—*i.e.* when the female is either known or suspected to play the chief rôle in courtship, her colours are generally more attractive than those of her mate; and we may conclude that her superior charms are due to the æsthetic preferences of the male. On all counts, therefore, it seems probable that beautiful colours constitute a definite part of the insects' courtship equipment. Nevertheless, a line must be drawn between colours of this kind and those which are merely crude and

conspicuous—*i.e.* warning colours. That this distinction actually obtains in nature is emphasized by Professor Poulton. "If an artist" (he writes), "entirely ignorant of natural history, were asked to arrange all the brightly coloured butterflies and moths in England in two divisions, the one containing all the beautiful patterns and combinations of colour, the other including the staring, strongly contrasted colours, and crude patterns, we should find that the latter would contain, with hardly an exception, the species in which independent evidence has shown, or is likely to show, the existence of some unpleasant quality. The former division would contain the colours displayed in courtship and when the insect is on the alert, concealed at other times."

Beetles often present very remarkable sex-differences, notably the great horns which are carried by many of the males. That these are frequently more ornamental than useful seems likely; but in some instances they are employed in love-warfare between rival suitors. Several males of the common stag-beetle (*Lucanus cervus*) at times pay court to the same female, and engage in fierce conflict for her possession. Another beetle, mentioned by Darwin, dwells in pairs in the same burrow during the breeding season, and when two insects have once set up housekeeping, woe betide the rival who may attempt to force an entrance. Not only does the male attack him fiercely, but the female stands on guard at the mouth of the burrow, and encourages her lord in his defence by pushing him from behind. Wallace, again, describes a conflict between two male beetles that were paying court to the same female, "who stood close by busy at her boring. They pushed each other with their rostra, and clawed and thumped, apparently in the greatest rage." Eventually the smaller beetle acknowledged his

defeat by running away. Darwin (in *The Descent of Man*) has given other instances, apparently well-authenticated, of contests between male saw-flies, digger-wasps, bees, and even butterflies for possession of a particular female. Unfortunately, such records are far less numerous than one could wish, and a wide field for discovery is open to those naturalists who, in the future, may make the courtship habits of insects their special study.

The nuptials of social insects, such as bees and ants, are in many ways unique, and influence profoundly the behaviour of the entire community. In a subsequent chapter we shall see that among bees the advent of a virgin queen is preceded by the issue of a swarm (headed by the old queen) which leaves the hive never to return. Subsequently the young queen escapes from her cell, and is at first ignored, not only by her sterile sisters, the workers, but also by the drones, with one of which she is destined to mate. For a while she wanders disconsolate in the dim recesses of the hive, then—doubtless impelled by instinct—she essays a short trial flight. She comes back to the hive almost immediately, as if alarmed at her own temerity; but a second sally is made a few seconds after the first; and then she ventures again and again until she feels herself mistress of her powers, and has become thoroughly acquainted with the environs of her metropolis. So far the drones have remained apathetic; but suddenly, from three to five days after the birth of the queen, they become conscious of her presence; and as she sets forth from the hive on what will prove to be her last excursion, she is followed by a bevy of ardent suitors. This, the wedding flight, usually takes place on a calm, warm day between the hours of twelve and four o'clock. The queen soars at an enormous speed far

up into the sky, and the drones give chase. Their huge eyes enable them to forestall the swervings of their quarry, while they are "gifted with a prodigious capacity for catching the magnetic queen-perfume by the thousands of sensory pits on their antennæ." Mating is accomplished in mid-air; one drone—presumably the swiftest and most alert—becomes the royal consort, perishing even as he triumphs. The widowed queen returns to her expectant subjects. As for the mob of unsuccessful drones, they will still be tolerated by the community if the year be young; but at the close of the summer, when their services can no longer be called for, they are ruthlessly driven from the hive and allowed to die.

So far as is known, the courtship of social wasps and humble-bees proceeds upon more conventional lines; but in the case of ants, whose communities continue from year to year, the males and females come forth in myriads from the nests at an appointed time—usually a still, hot day in August—leaving the workers behind them. But as the males are approximately equal to the females in number, the finding of partners must be a relatively simple matter. The males soon die after the nuptial flight, but such of the fertilised females as may escape destruction by insectivorous creatures cast their wings and become the foundresses of new colonies.

CHAPTER XVI

THE INSECT AS A PARENT

ALTHOUGH the majority of insects perish before their young come into existence, most of them are admirable parents in the sense that they make adequate provision for the well-being of the rising generation. It is true that some species, such as the stick-insects (*Phasmidæ*), simply discharge their eggs at random, allowing them to fall unheeded to the ground; but in these instances the eggs themselves are amply protected by their wonderful resemblance to seeds, while the newly hatched larvæ are well able to find their way back to the food plants. Most insects, however, oviposit in situations where the larvæ will be sure to find appropriate food. A few species actually keep watch over their eggs after they are laid. The common earwig is an admirable mother. She not only broods over her eggs, but takes the greatest care of them, collecting them into a heap if they are disturbed, and carrying them from one spot to another in order to secure the best position for their development. It is said that she is equally solicitous for the welfare of her young during the first few days of their life. The mole cricket also cares for her eggs, of which she lays from 200 to 400 in a specially constructed subterranean chamber, and supplies the young with food until their first moult, when the family disperses. Cockroaches are not known to foster their young, but the female carries her egg-case about with her until she finds a safe cranny in which to hide it, or until the eggs are almost ready to hatch. "On

a dark day in Washington" (writes Dr. Howard) "I once saw a migrating army of cockroaches, incalculable in number, crossing the street from a dirty restaurant toward buildings opposite. The majority of the individuals composing the army were females carrying egg-cases, and the observation thus became one of psychological interest since the migratory instinct seemed to have been developed by an appreciation of the fact that while the restaurant might support the mothers there would not be enough food for the coming children." Another American observer (Mr. H. G. Hubbard) has described the habits of certain bark-frequenting *Psocidæ* which feed upon lichens. The females watch over their eggs and lead forth the young in search of food, while the families remain together indefinitely, forming little flocks which include individuals of all ages. When danger threatens, they scatter like frightened sheep and take shelter in crevices of the bark; but they soon reassemble when their alarm subsides.

The invariable success of the mother-insect in selecting an appropriate spot for egg-laying is very remarkable. Yet the choice is purely instinctive. Impelled by impulses which she can neither ignore nor control, the butterfly forsakes the flowers, and among leaves of a thousand species picks out the one kind which will furnish her fastidious offspring with their ancestral food; the blood-sucking gnat launches her raft-like egg-mass upon the surface of the water—her larvæ being aquatic; the hover-fly, herself a pollen-feeder, must find aphides for the support of her young. Moreover, the act of oviposition is frequently accompanied by an elaborate ceremonial—as when a leaf is cut and rolled for the reception of the egg (page 122), or when the eggs are implanted deeply in the tissues of a plant (page 204). The sacred beetle watched by Fabre exercises great discrimination in pre-

paring the ball which is destined to contain her egg. This ball, which is fashioned during the autumn in a subterranean nursery, is quite distinct from those which the insect prepares in the springtime for the gratification of her own appetite. The necessary materials having been collected, the Scarabæus settles down to her task. "The first thing to do is to select very carefully, taking what is most delicate for the inner layers, upon which the larva will feed, and the coarser for the outer ones which merely serve as a protecting shell. Then, around a central hollow which receives the egg, the materials must be arranged layer after layer, according to their decreasing fineness and nutritive value; the strata must be made consistent and adhere one to another; and finally, the bits of fibre in the outer crust, which has to protect the whole thing, must be felted together. How can the Scarabæus, clumsy and stiff as it seems, accomplish such a work in complete darkness, at the bottom of a hole so full of provisions that there is barely room to move? . . . Explain who can this miracle of maternal industry." Nor is this all, for Fabre found that the mother beetle regurgitates a partially digested paste which is added to the layer immediately surrounding the egg, thus providing an easily assimilated first meal for her offspring.

Still more remarkable are the habits of those insects which, by their instinctive preparations, enable their young to live at the expense of others. The female ichneumon lays her eggs either in or upon the body of another insect, usually a caterpillar, which is thus doomed to become the "host" upon whose substance the parasite larvæ will fatten. One small Braconid ichneumon (*Microgaster glomeratus*) lays its eggs in the caterpillars of the large-white butterfly —usually in such numbers that when the caterpillar is full-grown its skin is literally packed with the alien grubs,

which eventually eat their way out and spin their small, yellow cocoons in a mass above the shrivelled remains of their victim. The members of the large families *Chalcididæ* and *Proctotrypidæ* are less beholden to caterpillars than the true ichneumons. Many of them oviposit in pupæ, many in the eggs of other insects and spiders, while some patronise aphides. The extreme minuteness of many of these insects may be judged from the fact that in some instances half-a-dozen or more parasite grubs find sufficient nourishment for their development in the contents of a single butterfly's egg.

Like the ichneumons, the Tachinid flies select caterpillars as hosts for their larvæ. Their eggs are never laid within the creature's tissues, however, but are fixed to its skin by means of a gummy secretion. The minute larva is left to penetrate the egg-shell on its underside, and make its way into the victim's body. Moreover, the instinctive shrewdness of the ichneumon far surpasses that of her competitor the Tachinid. The latter frequently glues her eggs to the back of a caterpillar that is about to change its skin; and when this happens the caterpillar simply discards its old coat and the eggs along with it, thus escaping destruction. Again, a fly will often attach three or four times too many eggs to a caterpillar, with the result that most of her grubs perish from want of food, while the remainder are half-starved and produced dwarfed imagines. Ichneumons, on the other hand, scarcely ever make mistakes. They seem to know by a touch of the antennæ whether a caterpillar has been "stung" by some earlier visitor, and if this proves to be the case, they rarely insert their own eggs; nor do they fall into the error of overburdening a host. These comparisons suggest that Tachinid flies are probably new to the business in which they engage. We may suppose that, like many of their

near allies, they once laid their eggs in carrion or refuse, and that the parasitic mode has been adopted in comparatively recent times. This view is supported by the additional fact that Tachinids usually lay their eggs upon any caterpillar that they chance to encounter ; whereas a given species of ichneumon commonly confines itself to one kind of host.

The maternal instincts of bot-flies (*Œstridæ*) lead to parasitism of a peculiarly revolting kind. The eggs of the warble-fly (***Hypoderma***), laid by the parent insect upon the hairs of a cow or an ox, are licked off and swallowed by the unsuspecting beast. The newly-hatched larvæ penetrate the wall of its œsophagus, and burrow through the tissues until they arrive at points along the back, just under the skin, where they complete their growth. They eventually fall to the ground in order to assume the pupa state. The presence of these "bots" beneath the skin gives rise to more or less serious sores, while the hides of badly infested animals are rendered almost valueless on account of the holes made by the parasites. The larvæ of other bot-flies develop in the stomach of their host, or in the sinuses of its head which they reach through the nostrils. These habits appear very remarkable when we remember that the adult insects resort to their victims solely for the purpose of egg-laying. They cannot suck blood or avail themselves of any other kind of food, for their mouths are reduced to mere functionless pores. Their sole office in life is to prepare the way for a debased but pre-eminently safe existence on the part of their progeny.

It is a relief to turn from these sordid details to the nesting habits of the higher Hymenoptera. True, among wasps, we find much callous butchering ; but this is always accomplished in such a straightforward manner that criti-

cism is disarmed. The large Scoliid wasps simply paralyse their prey where they find it, and lay an egg on its body —thus providing their grub with a store of fresh meat. The true digger-wasps of the families *Sphegidæ* and *Pompilidæ* go further, laying up the food in a specially constructed nursery, which may take the form of a subterranean chamber, a tunnel driven in the stem of a plant, or an earthenware cell built up from clay mingled with the insect's adhesive saliva. One of the best-known Sphegid wasps is *Ammophila sabulosa*, whose behaviour has been carefully watched by Fabre and other observers. The female first sinks a vertical shaft into the ground and excavates a single cell about two inches below the surface. When the burrow is complete the wasp carefully closes the entrance with a small stone. She then hurries off, but returns sooner or later dragging a caterpillar which she has paralysed with her sting—thereby rendering her task more easy and preventing the victim's escape. When the caterpillar has been stored an egg is laid, and the cell is permanently closed. Thus, when the young wasp-grub hatches it finds itself safely housed and amply provided with food.

Like so many other insects, these digger-wasps are extremely conservative in their choice of food. Some take caterpillars of a special kind, some two-winged flies, some hard beetles. Certain of the smaller species prey exclusively upon aphides, while at least one is known to take "cuckoo-spit" nymphs from the midst of their frothy surroundings.

The Pompilids are spider-killers almost without exception, and some of them display no little temerity in their hunting. A species of *Calicurgus*, observed by Fabre, does not enter the spider's den, for if she did so the owner would destroy her with its poisonous fangs. She therefore

dodges about the entrance until the enraged occupant is induced to show itself, when the wasp instantly grips one of its legs with her jaws and pulls with all her might. If the spider proves the stronger, the insect relinquishes her hold and seeks another den, where the same tactics are repeated. Sooner or later she manages to drag a spider from its stronghold, when she pounces upon it and inflicts the *coup de grâce* with her sting.

Most digger-wasps simply close up their cells after the egg has been laid, and never return to them again. The mother instinctively stores a sufficiency of food for the needs of the grub. But wasps of the genus *Bembex* and their allies are exceptions. Unfortunately there is no British representative of this interesting group, but the habits of certain European and North American species have been carefully investigated. The nests are formed in dry, sandy spots. The prey consists of Diptera of various kinds; but instead of laying up a heap of carcases the mother wasp glues her egg to the side of one small fly, and then closes the entrance to the burrow. Two or three days later the egg hatches, and the larva consumes the soft parts of the fly. Meanwhile the mother remains in the vicinity, and at the crucial moment brings another fly slightly larger than the first. She does this again and again for about a fortnight, until her offspring refuses food and is ready to spin its cocoon. In the case of *Bembex rostrata* Fabre found that from fifty to eighty flies may be required before the grub shows signs of repletion. A small *Syrphus* or a bright green flesh-fly is generally utilised for the first meal, but afterwards the game consists of large blood-sucking gad-flies (*Tabanidæ*). Whether a *Bembex* ever sets up more than one nursing establishment at the same time is a question which has not yet been settled. The American species (*Bembex*

spinolæ), watched by Mr. and Mrs. Peckham, appears not to do so. "To determine this point" (say these observers) "we marked six wasps by touching them with differently coloured paints, putting near their nests pebbles painted to correspond with the owners, and then watched them closely for three hours. During this time the red wasp returned regularly to the red nest, the blue to the blue, and so on. They were watched for an hour and a half on the following day with the same result, so that it seems quite certain that *spinolæ* has only one nest at a time."

The solitary true wasps, which make up the sub-family *Eumeninæ* (page 99), are represented in Britain by some sixteen species. Their habits resemble those of the diggers in many respects, but they usually provision their cells with small caterpillars, while most of them are inveterate mud-daubers. One of our species (*Eumenes coarctata*) constructs a little vase-like cell, usually upon a twig of heath or some low-growing shrub; the others, which are all included in the genus *Odynerus*, make their nests in crevices of walls, in hollowed-out plant stems, or in subterranean burrows; while they occasionally adopt such unconventional nesting-sites as door-locks, reels of cotton, or even pistol-barrels.

The solitary bees nest in a great variety of ways. Many burrow into the ground, others into pith or wood, while some construct earthen chambers in any suitable crevice, or openly upon stones or masonry. In all cases, however, the cells are stored with a mixture of honey and pollen. The nurseries of the more primitive bees are usually mere tunnels connecting a series of brood-chambers, each of which contains an egg and the appointed allowance of food. When the arrangements are complete, the entrance to the tunnel is closed, the young being left to their own devices. But many of the

more advanced species are accomplished architects. The large and powerful carpenter bees burrow into timber, and partition off their cells with wood chips mixed with their glue-like saliva. Mason bees employ the same kind of adhesive when preparing their concrete. But the most interesting of all the solitary bees are the leaf-cutters. There are several British species, the best-known being *Megachile willughbiella.* The female first drives a burrow in a rotten beam, post, or tree trunk, and then proceeds to fill it with cells formed from pieces of rose leaf. She alights upon a leaf, grasping with her legs the portion she is about to remove. Then with her mandibles she makes a rapid, curving cut; and just as she severs the last shred of her support, her wings begin to vibrate, and she soars away with her spoil held firmly beneath her body. First lozenge-shaped pieces of leaf are cut and rammed into place to form a thimble-shaped cell, which is provisioned with honey and pollen. Thereafter the egg is laid, and the cell is closed with a wad of leaf fragments more or less circular in outline. At least seven lozenge-shaped and four circular pieces are cut and carried by this industrious insect to form a single cell.

A whole host of bees make no direct provision for their young. They are not actually parasites, but—like the cuckoo among birds—lay their eggs in the nests of other species. One example will suffice to make clear the nature of the relationship. The leaf-cutting bee forms her cell, provisions it, and lays her egg. When she is absent cutting the leaf fragments to cap the cell, a cuckoo bee (*Cœlioxys conoidea*) steals into the tunnel and lays her own egg side by side with that of the owner. The usual result is that the cuckoo's grub (whose egg is the first to hatch) devours most of the food, while the leaf-cutter's grub is starved. Some of these cuckoo grubs so far forget

PLATE XXXVIII

Rose leaves mutilated by Leaf-cutting Bee

Female Leaf-cutting Bee (*Megachile willughbiella*) with eleven pieces of leaf which are used to form a single cell

themselves as to kill and eat the proper occupant of the nursery after robbing it of its food.

None of the true digger-wasps are guilty of this underhand behaviour; but the dainty little ruby wasps (*Chrysididæ*) are "cuckoos" one and all, in the sense that they lay their eggs in the nests of other Hymenoptera. In most cases, however, it is believed that the alien larva does not eat the stored food, but waits patiently until the wasp larva has finished feeding, and then devours *it*. Indeed, the parental activities of insects range from honest labour of the most toilsome kind, through every conceivable grade of shiftlessness and trickery, to the grossest parasitism. Moreover, these varied conditions are often intermingled in a manner which well-nigh baffles description. Some of the gall-wasps, for example, have an extraordinary number of dependents. These may be roughly divided into three groups. First, inquilines—species which do not themselves make galls, but lay their eggs in galls already formed; their larvæ feed upon the substance of the gall, but often, though not invariably, kill the offspring of the actual maker by pressure. Secondly, true parasites, which thrust their ovipositors into the gall and lay their eggs in or near to the bodies of the rightful tenants—or it may be the bodies of the inquilines. Thirdly, commensals—messmates as it were—which feed upon the tissues of the gall without encroaching upon the rights of the inmates. From a mass of oak-apples, the late Mr. Francis Walker reared seventy-five species of insects, representing seven orders, not to mention a few spiders and mites. In all there were upwards of 55,000 individuals! Needless to say, the precise status of many of these hangers-on remains obscure; but we may take it that they are all beholden, either directly or indirectly, to the original gall-maker.

As might be expected, the parental instincts of insects are most strongly marked among the social groups. Indeed, in the case of the Hymenoptera, at least, we shall see that they constitute the foundation upon which the whole superstructure of insect communism is based; for a bee-hive or an ants' nest is neither more nor less than a vast co-operative nursing establishment. The extraordinary caste system has been evolved in order that a few individuals may devote their energies exclusively to procreation, while a vast army of helpers is at hand to care for the enormous and ever-growing family. With these matters we shall deal more fully in the next chapter.

Among insects in general the male is exempt from family cares; but there are several interesting exceptions. Certain bark-beetles (*Scolytidæ*) are polygamous, and in these species the male exerts himself to form a circular excavation beneath the bark, wherein he receives the members of his harem. The females, however, construct their respective brood-galleries, which radiate from the nuptial chamber. We have already seen that sexton beetles (*Necrophorus*) of both sexes labour in company to bury the carcass in which the eggs are to be laid. A similar co-operation seems to occur among some of the scavenger beetles, although in other species, according to Fabre, the female receives no assistance from her mate. Among the large water-bugs of the genus *Zaitha*, the eggs are carried on the back of the adult insect, and until recently the female was assumed to be the bearer. But observations made by an American lady, Miss Slater, have established the remarkable fact that the female actually captures a male and deliberately glues her eggs to his back. "That the male chafes under the burden is unmistakable; in fact my suspicions as to the sex of the egg-carrier were first aroused by watching one in an

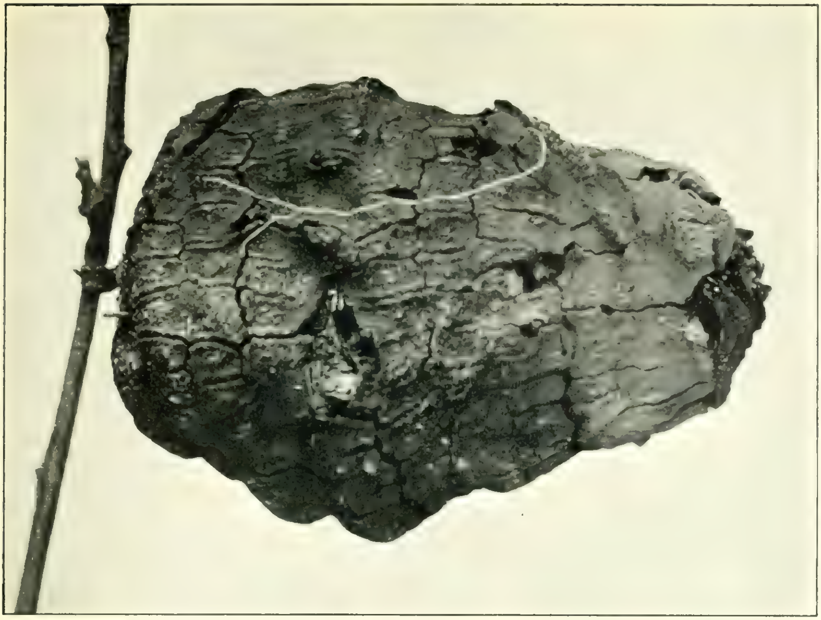
aquarium which was trying to free itself from its load of eggs, an exhibition of a lack of maternal interest not to be expected in a female carrying her own eggs. Generally the Zaithas are very active, darting about with great rapidity; but an egg-bearer remains quietly clinging to a leaf with the end of the abdomen just out of the water. If attacked, he meekly received the blows, seemingly preferring death, which in several cases was the result, to the indignity of carrying and caring for the eggs."

CHAPTER XVII

INSECT COMMUNITIES

The vast majority of insects pass their lives in solitude. But exceptions to this rule occur throughout the orders, while among ants, bees, and wasps, and "white ants" or termites, we find co-operative associations which are without parallel in the whole animal kingdom. These must have sprung from small beginnings. The remote ancestors of the hive-bee, that paragon of civic virtues, were doubtless wanderers upon the face of the earth. True, insects have no sagas. No musty chronicles exist to tell us how they fared in long-past ages. But in the lives of insects to-day we may read, if we will, some record of their history.

Social life in its most simple form is typified by many caterpillars which weave, by their united effort, a web of silk over their food plant, thus forming a kind of tent which shelters the whole brood. Sometimes these tents are very stoutly wrought, and are tenanted throughout the winter; or they may be mere booths which are renewed from time to time in accordance with the needs of their inmates. These social caterpillars often display remarkable unity of action. They have set times for feeding, for basking in the sun outside their tent, and for resting within its shelter; and when one individual moves, the rest all follow. The caterpillars of the European processionary moth (*Cnethocampa processionea*) leave their nest at sundown, and march to their feeding grounds in wedge-shaped order. It is said that the pioneer emits a



Hanging nest of a species of Termite

Social Caterpillars of Lackey Moth (*Clisiocampa neustria*) basking in the sun outside their tent

silken thread to which the leaders of succeeding files attach threads of their own making, thus bringing the whole column into unison. Caterpillar colonies usually break up when a certain stage of growth is reached, or when the food supply in the neighbourhood of their nest is exhausted; but certain species are continuously gregarious, and eventually spin compound cocoons.

Insects sometimes assemble in vast companies for the purpose of travel, certain kinds of larvæ having gained the title of "army worms" on this account. For some unexplained reason, the half-grown larvæ of a "wainscot" moth (*Leucania unipunctata*) suddenly become gregarious, and migrate in vast hordes which overrun grass and corn lands, where they work incalculable havoc. These invasions take place in North America, but the species is almost cosmopolitan, and its native country is unknown. Other so-called "army worms" are the maggots of small midges belonging to the genus *Sciara*. They live under layers of rotting leaves in the forests of Northern Europe, and at times migrate from one feeding ground to another in weird, snake-like columns. Millions of the maggots, held together by their viscous secretions, form great strings or ribbons several inches thick and many feet in length. At the end of their journey they collect into one writhing mass, which is slowly dissipated as its units burrow beneath the leaves in search of food. These processional maggots are also found in the United States.

Certain adult insects habitually congregate in flocks after the manner of birds, and it is noteworthy that these gatherings usually consist of males only. The writer has seen thousands of chafer beetles flying about street lamps. Some hundreds were caught and examined, but not a single female was found. Clouds of male flies of the genus *Bibio* may often be observed in rapid, whirling

flight above the waters of a pond, while male gnats are sometimes so numerous as to form a flickering haze in the evening air.

Vast swarms of butterflies have been encountered by ships far from land. A few species are known to migrate annually along definite courses, and to have extended their range in historic times. The American monarch butterfly (*Anosia plexippus*) has already been mentioned. It is evidently tropical in its origin, yet in the summer season it ranges far northward into Canada in search of food-plants for its young. At the approach of winter the butterflies of the new generation congregate in flocks, and commence their southward journey, resting at night among herbage and the branches of trees. Those individuals that fail to join in the flight to warmer climes appear to perish, for no hibernating monarchs have been found in the northern States or in Canada.

The gregarious habits and migratory instincts of locusts have been closely studied. These insects usually breed on dry and rather elevated plains, whence they sally in immense and devastating swarms. A writer in *Nature* states that a flight of locusts passed over the Red Sea in November 1889. It appeared to be 2000 miles in extent, and he estimated its weight at 42,850 millions of tons, reckoning each locust as one-sixteenth of an ounce. Independent testimony and official statistics tend to support the accuracy of these figures. The fact that locusts usually invade districts at irregular intervals, and not in succeeding years, seems to indicate that the migratory instinct is called forth by over-population of their breeding haunts. Favourable climatic conditions, and relative freedom from the attacks of parasites, apparently combine in some seasons to foster excessive increase, and the insects must either migrate or starve. Instincts which

have been in abeyance, perhaps for a decade, resume their sway, and the swarms set forth along the same courses which were followed by their ancestors. Locusts seem to rely mainly upon air currents in their journeyings, and to make little use of their wings. They are known to make trial flights in order to ascertain the direction of the wind. When this proves favourable, the whole swarm rises, and is carried forward without effort. The migratory instinct in some locusts arises in the young before the wings are developed, and long journeys are accomplished afoot. Dr. David Sharp, quoting from an account by Mrs. Barber, gives interesting particulars as to the manner in which rivers are crossed by these youthful emigrants, which are called "Voetgangers" by the Dutch in South Africa. "It is a common practice for the young locusts to form a bridge over a moderately broad stream by plunging indiscriminately into it and holding on to each other, grappling like drowning men at sticks or straws, or, in fact, anything that comes within their reach, and that will assist in floating them; meanwhile those from behind are eagerly pushing forward over the bodies of those that are already in the stream and hurrying on to the front, until at length by this process they reach the opposite bank of the river; thus a floating mass of living locusts is stretched across the stream, forming a bridge over which the whole swarm passes. In this manner few, comparatively speaking, are drowned, because the same individuals do not remain in the water during the whole of the time occupied by the swarm in crossing, the insects continually changing places with each other; those that are beneath are endeavouring to reach the surface by climbing over others, whilst those above them are, in their turn, being forced below. Locusts are exceedingly tenacious of life, remaining under water for a considerable time

without injury. An apparently drowned locust will revive beneath the warm rays of the sun, if by chance it reaches the bank or is cast on shore."

These associations of insects for mutual advantage, or for the purpose of travel, suggest the first glimmering of the clannish instinct; but no direct connection exists between mere gregariousness and the true social habits which have reference to the welfare of the young. Among the Hymenoptera we may trace the evolution of communism, in an ascending scale, from parental instinct in its most rudimentary form. The leaf-eating larva of a saw-fly is left to fend entirely for itself; but the ichneumon lays her egg in or upon the living caterpillar that is to provide food for her offspring. A Scoliid wasp paralyses its victim before the egg is laid. The true digger-wasps go further, forming nests and storing them with caterpillars and other insects. The activities of *Ammophila* have already been described; while an intermediate link is supplied by some of the spider-hunting wasps (*Pompilidæ*), which first capture their prey and then prepare a hole for its reception. Such instances serve to illustrate the building up of instinct; and among the burrowing bees the progress from the solitary to the social habit is no less evident. "All these insects," writes Professor Carpenter, "show great care for their young, storing up food for their sustenance, and building nests for their protection. In most cases the food is stored, the egg laid, and the cell sealed up, the mother never watching the growth of her offspring. But the digger-wasp Bembex leaves the cells open, and brings fresh supplies of flies to her grubs every day. Here, then, we have a family life comparable to that of birds. It often happens that a number of the 'solitary' wasps or bees . . . form their nests close together, making an imperfect colony, or that a number

of them pass the winter in company in some sheltered spot. But it is not apparently thus that the true social communities have been elaborated; these, like human states, have their origin in the family. For these communities three conditions are necessary—a nest large enough for a number of insects, a close grouping of the cells, and an association between mother and offspring in the perfect state. The last condition will be brought about by the emergence of the older insects of the brood while the mother is still occupied with the younger larvæ or their cells. In a single species of solitary bee (*Halictus quadristrigatus*) these conditions are almost fulfilled, but the first young insects to appear are males, and when the females are developed the mother dies."

The small bees of the genus *Halictus* are in many respects more advanced than any of their solitary congeners, and among certain species Fabre has observed a marked tendency towards co-operation. A number of females combine to form a common burrow which gives access to the various groups of cells. There is also a vestibule, or widening of the burrow near the opening, which enables the bees to pass one another easily as they go in and out, while a sentinel bee is posted to guard the entrance. But there is no worker class. Each female constructs and provisions her own set of cells after the manner of solitary bees in general. The condition of *Halictus,* indeed, has been aptly compared to that of families occupying a model dwelling, each separate and distinct, but using a common stair and the same street door. In one other point the genus *Halictus* foreshadows the true social groups. Usually the males and females emerge late in the season, and although pairing takes place, no new burrows are formed. The males perish as winter approaches, but the females retire to the old

burrows, where they remain until the following spring, when they commence preparations for the new brood. Most other solitary bees remain in their cells as larvæ or pupæ throughout the winter, the sexes issuing together during spring or early summer.

Humble-bees exemplify the true social community in its simplest form. The mother bee, or "queen," becomes the foundress of a co-operative colony, which ultimately includes a preponderance of workers—*i.e.* small, imperfectly developed females, which act as nurses, foragers, and builders. Some humble-bees build their nests in holes, others upon the surface of the ground beneath a pile of moss or vegetable débris. The queen of a subterranean species, such as our black-and-yellow banded humble-bee with a tawny tail (*Bombus terrestris*), often takes possession of a ready-made cavity, such as the deserted burrow of a field mouse. Here she constructs a rough cell, using a waxy substance, and coats the inner walls liberally with honey-saturated pollen. Four or five eggs are then laid, and the cell is closed; but it is reopened from time to time as the growing grubs require more food. The queen's next care is to make one or two cells which she fills with pollen and honey, these reservoirs being drawn upon in rainy weather when food cannot be gathered direct from the flowers. Thereafter she proceeds to fashion more brood cells, and to lay more eggs, labouring the while to provide food for the grubs which have already hatched. As the latter increase in size they press against the soft walls around them, while the queen continually adds fresh layers from without; so that the cell gradually becomes an irregular truffle-like mass. When full-grown, each grub spins an ovoid silken cocoon.

In favourable circumstances the development of the

humble-bee, from egg to perfect insect, occupies from three to four weeks; so that the queen is soon surrounded by a little band of four or five workers, the product of the first brood cell, each ready to bear a part in the labours of the day; while as the summer advances the number of these workers steadily increases, and the colony prospers. The queen continues to lay eggs; the workers feed the grubs and go abroad in search of honey and pollen. But the social castes of the humble-bee are not rigidly separated as in the case of the wasp. Communities of the latter insect, as we shall see, are made up of one ruling queen and a vast number of workers. Among the humble-bees the fertile females merge, as it were, into the worker caste. Those individuals which are reared in the first-made cells are almost always true workers; but when a nest is established, and its prosperity is assured, numerous small queens are often produced. These live amicably with the original queen, and supplement her egg-laying powers. Moreover, the workers vary among themselves, and their size seems to determine the kind of labour which they are called upon to perform. The larger individuals collect food and building materials, while their smaller sisters usually remain at home, where they act as nurses to the grubs. As autumn approaches a brood of males or "drones" is produced, as well as a number of large queens—the latter being destined to survive the winter and perpetuate the species in the succeeding year. A humble-bee colony is never very numerous. A nest of *Bombus terrestris* may have a population of from 300 to 400 individuals when the drones begin to appear; but some of the species which make their homes above ground never exceed a score or two of individuals.

Some humble-bees are known popularly as "carders" because they thatch their habitations with the closely

woven fibres of grass or moss. Such nests are often approached through an arched passage of the same material, and are usually cunningly hidden amongst the herbage. But carder bees readily adapt themselves to circumstances, and have been known to make their homes in such places as straw-filled packing-cases or deserted birds' nests. In one instance a carder bee (*Bombus agrorum*) actually invaded a wren's nest, and heaped up its brood cells amongst the eggs, which were eventually deserted by the parent bird. Another little humble-bee family flourished for a time in the mud-walled habitation of a house-martin, from which the rightful owners had apparently been evicted; but the bees, in their turn, were subsequently victimised by the social caterpillars of a small moth (*Aphomia sociella*) which feed upon wax and similar substances. These laid waste the bees' nest, ultimately spinning their cocoons amongst the wreckage.

Parasites and guest insects, or inquilines, are very numerous in the nests of humble-bees. Some seem to play the part of scavengers, and to be tolerated for this reason. For example, the grubs of the two-winged flies known as *Volucella* appear to eat what the bee larvæ reject; whereas the grubs of other flies and certain beetles are pestilential scourges which destroy both larvæ and pupæ, and effect the downfall of the community. The cuckoo humble-bees of the genus *Psithyrus* (*Apathus* of some authors) resemble their hosts so closely that it is difficult to tell them apart without close scrutiny. But they have no workers, and the females lack food-gathering appliances—notably the pollen-baskets of the hind tibiæ. Unfitted to perform their own domestic duties, they take up their abode in the nests of social humble-bees; and strangely enough each species of *Psithyrus* usually resembles in colouring the *Bombus*

with which it lives. Apparently the intruders possess suave manners, for the alarm and resentment aroused by their entry soon give place to harmony. Not only are the *Psithyrus* grubs fed and tended by the *Bombus* workers, but the adult insects of both sexes consume much nectar from the common store, with the result that the increase of the community is seriously hampered. A nest infested by *Psithyrus* was found, in September, to contain only one *Bombus* queen and fifteen workers; yet in normal circumstances the same species of humble-bee would have increased during the summer to at least 200. The ultimate success of a humble-bee community is in ratio to the number of young queens which are reared at the close of the season. These alone survive the winter; and when their nuptials are accomplished, the prosperity of the nest declines, while its whole population of drones and workers perishes when the first severe frosts set in.

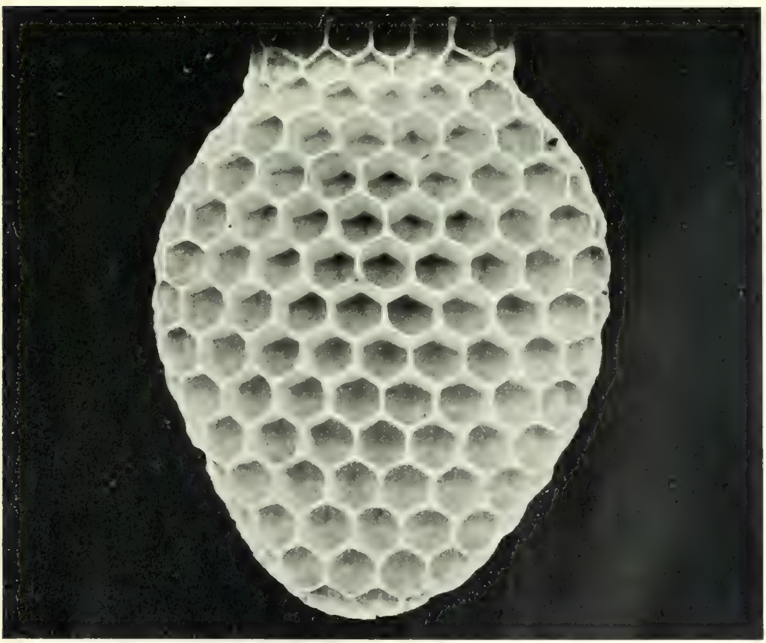
The tropical Meliponas or "mosquito bees" (so called on account of their diminutive size) appear to form a connecting link between humble-bees and hive-bees, though little is yet known of their life-histories and habits. They nest in hollow trees, form definite combs of waxen cells, and often amass rich stores of honey. A colony comprises the usual castes; but the drones are said to take part in the labours of the community, while there is reason for thinking that more than one queen may be tolerated in each nest. It is also believed that a complete ration of pollen and honey is placed with the egg in the cell, the latter being then sealed down by the workers—a primitive method of feeding reminiscent of the solitary bees. The Meliponas are either unable or unwilling to sting; but they fight desperately with their mandibles, and have highly developed instincts. Many of them are clever

artisans and builders. Some species use clay, in addition to wax and resin, when constructing their outworks.

The notion that a queen hive-bee (*Apis mellifica*) governs her subjects is incorrect. Owing to a peculiar physical endowment she is indeed able to determine the sex of her offspring; yet there is no proof that she voluntarily exercises even this limited power. Certain it is that the female larva develops into a queen or a worker in accordance with the kind of food supplied by its nurses. Moreover, in all other matters the queen is a slave of the community—a mere egg-laying machine which may be accelerated or retarded at will. When the affairs of the hive are in the ascendant, and the need for fresh relays of workers is urgent, the queen is pampered with dainty rations, and led from cell to cell, in each of which she leaves an egg; but when the tide of prosperity turns, she is literally starved into submission, and her fertility is checked. In a word, the government of the bee-state is vested in the workers; and they themselves are impelled by instincts, the sum of which has been aptly termed "the spirit of the hive."

The hive-bee has been more closely studied than any other insect, the wonders of its structure and life being set forth in a whole library of volumes. For our present purpose a brief summary must suffice. Let us suppose that we take our first peep into a hive when the work of the year is commencing. The population consists of one queen and a fairly numerous body of workers which have survived the winter in company, eking out their provisions, and clustering together for warmth. When flowers begin to open, many workers go forth to collect nectar and pollen. Others busy themselves with the building of new comb to accommodate the daily growing store of food-substances, and to receive the eggs from which new

Nest of Wasp (*Vespa vulgaris*); the unaided work of the queen before the emergence of workers. (Natural size)



Drone comb of Hive-bee (*Apis mellifica*)

broods of workers will be reared. Superfluous openings in the walls of the hive are stopped up with propolis, a resinous substance collected principally from the buds of plants; but the comb is always formed of wax. This is really a manufactured article. The workers first gorge themselves with nectar or honey, and then hang in a dense, heated festoon until wax issues in the form of scales between the ventral plates of the abdomen. These scales are subsequently amalgamated and rendered plastic by mastication with the bees' saliva.

The cells of the hive-bee may be described as hexagonal vessels, set almost horizontally in two series back to back in such a way that the base of one cell is formed by the union of the bases of three opposite cells. Mathematicians concede that they afford the utmost capacity obtainable from the material expended. Moreover, the six-sided vessels, with their slight upward tilt, are very retentive of liquid. Nevertheless: "It has been shown," writes Mr. T. W. Cowan, "that the complexity and apparent accuracy of the structure is not in the least owing to the development of a mathematical instinct in bees, or to artistic dexterity, but simply to physical laws dependent upon their method of work, or as Müllenhoff puts it, to 'statical pressure according to the laws of equilibrium.'" Cells destined for the rearing of workers, or for the purpose of storage, are one-fifth of an inch in diameter. These make up the bulk of the comb. But there is also a limited number of larger cells, one-quarter of an inch in diameter, which are used as nurseries for the drones. Queen or royal cells are relatively large, thimble-shaped structures which hang with their openings downward from the edges of the comb.

In the height of the breeding season, the queen, surrounded by her attendants, passes rapidly from one cell

to another, fixing an egg to the inner wall of each at the rate of one hundred or more per hour. The eggs hatch in about three days, and the young larvæ are at first fed upon a kind of pap ("chyle-food") which is regurgitated by the nurse workers; but in three days weaning takes place, pollen and honey being added to the regime. In five days the larva is full-fed, and ready to spin its cocoon. Its cell is then sealed down by the workers with a porous capping of wax mixed with pollen. Pupation occupies thirteen days; then, about twenty-one days after the egg was laid, the perfect worker bee bites round the roof of her nursery and mingles with the teeming population of the hive. She is at first weak and wan, but at the expiration of four-and-twenty hours is ready to commence work as a nurse. She does not venture from the hive to collect nectar and pollen until ten or twelve days later.

As the season advances, from three to four hundred drones are reared in the larger cells specially prepared for the purpose. The eggs which the queen lays in these cells are unimpregnated, and invariably produce male insects. Drones take twenty-four days from the laying of the egg to reach maturity.

When the increase of the worker population threatens to overtax the capacity of the hive, a few royal cells are prepared. The eggs laid therein are identical with those which are supplied by the queen to worker cells; but these royal grubs are fed exclusively upon chyle-food. The effect of this is to promote full and rapid physical development, so that a young princess can be reared in from fifteen to seventeen days.

Now commences that remarkable series of phenomena known as "swarming." The old queen evinces signs of ungovernable excitement when she hears the young princesses piping in their cells. The work of the community

is temporarily suspended, while many of the workers gorge themselves with honey. Scouts are sent out to explore the neighbourhood; and ere long a great swarm of emigrants, headed by the queen and accompanied by a few of the drones, issues from the hive. They fly round in an agitated crowd, but at length gather in a great cluster on the branch of a tree, or some other convenient spot, where the queen has settled. The practical bee-keeper may now readily "take the swarm"—*i.e.* accommodate the bees with a new hive; but in default of this attention the insects will shelter in a hollow tree, among the rafters of a shed or outhouse, or in some similar situation. The workers at once construct brood comb in which the queen lays eggs, and in this way a new community is founded. Meantime, in the parent hive, a princess has escaped from her cell. Her first act is to tear open the remaining royal cells, and sting their inmates to death. About a week later she leaves the hive for her nuptial flight, followed by a bevy of drones; and, on her return, settles down to her task of egg-laying. But should the stock be strong and the hive incommodious a second swarm or "cast" may be sent out nine days after the first. When this happens, the omnipotent workers prevent the young queen from destroying her imprisoned sisters; while if, as is sometimes the case, no swarms at all are sent forth, the old queen may be crushed to death by the workers, one of the young queens being installed in her place. In any event, a community of hive-bees, when once established, has within itself the power indefinitely to renew its youth. The individual worker lives only about two months; but fresh generations pour from the combs throughout the summer; while the latest brood of the season survives the winter and gathers up the threads of progress when spring returns. The queen

may persist for three or four years; but at the first signs of waning fertility she is deposed in favour of a youthful successor. Thus the commonwealth of the hive endures.

Some tropical wasps construct very durable nests, and are known to store up food after the manner of bees; while others are said to found new colonies by swarming. The best-known species, however, resemble humble-bees in the fact that their communities last only from spring to autumn. Including the hornet, we have seven kinds of social wasps in Britain, and these build in three different ways. The two species of "common wasps" (*Vespa vulgaris* and *V. germanica*), and that known as *V. rufa*, inhabit subterranean chambers; *V. arborea*, *V. sylvestris*, and *V. norvegica* suspend their nests from the branches of trees and shrubs; while the hornet (*V. crabro*) usually builds above ground, but under cover, a favourite situation being a hollow tree, or beneath the thatched roof of a cottage or outhouse.

A queen of *V. vulgaris*, after hibernating, seeks out a cavity from the roof of which at least one substantial root protrudes. She then flies to a fence or gate-post, and with her mandibles rasps away a bundle of wood-fibre. This she macerates with her saliva, and thus works up a kind of coarse brown paper which is the time-honoured building material of her race. The first little pellet is spread upon the root in the nest-hole. Hour after hour the queen repeats her journeys, always returning with another pellet which she adds carefully to the existing evidence of her toil. In this way she constructs a short triangular foot-stalk, attaches to it several cells, and shelters them beneath an umbrella-like canopy, which is subsequently enlarged to form a globular covering. In each cell an egg is laid; and when the grubs hatch the queen assumes the rôle of nurse, although she continues to

fashion more cells and to lay more eggs. A time comes, however, when her powers of paper-making fail; but this is coincident with the maturing of the older grubs, which change to pupæ, and issue from their cells as fully equipped workers. Then the queen devotes all her energies to the task of egg-laying, while the workers feed the grubs, extend the nest, and labour to promote the common weal. The original comb of cells formed by the queen is widened, and new combs are suspended from it by papier-maché stalks.

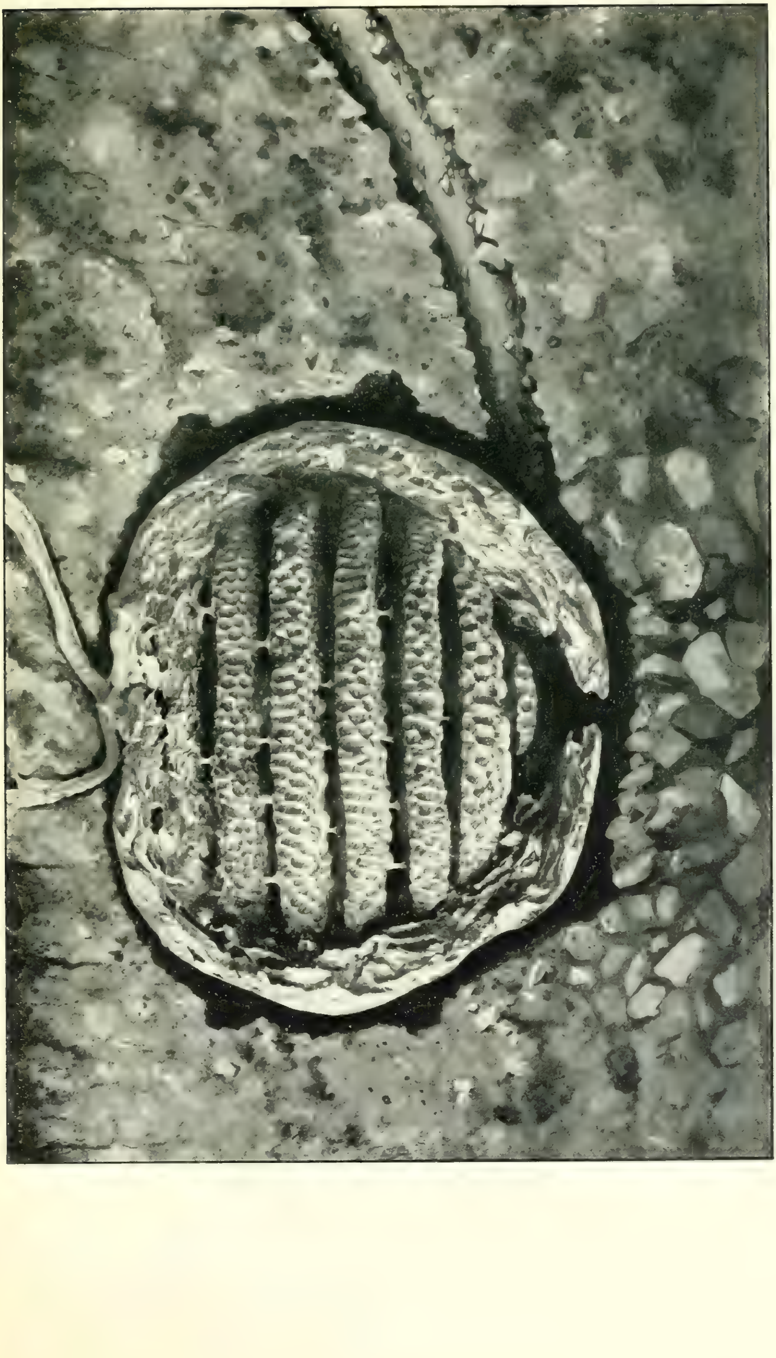
It is a peculiarity of wasp architecture that although the nest grows steadily from day to day it never appears unfinished. The outer covering is always round, shapely, and perfectly closed, save for the single entrance hole below. As the combs are extended, the protecting cover is gradually cut away from within and replaced by fresh layers from without. This method necessitates a much greater expenditure of labour and material than would be needed if the nest could be planned on a much larger scale at the outset, especially as wasps rarely use over again the old paper that they cut away. But the nest must be kept constantly closed in order that the grubs may be sheltered from cold and draught. Moreover, the labour necessary for conducting building operations on an extensive scale is not forthcoming during the early periods of the nest's history.

As the nest grows steadily from day to day, it is clear that the workers must devote much time to the enlargement of the cavity which contains it. Fragments of soil and small stones are carried out bodily; but those which are too heavy for the insects to lift are carefully undermined, and allowed to gravitate to the floor of the cavern. If it were possible to make a clean cut right through a bank containing a populous wasps' nest, we should obtain

a section similar to that which is portrayed on Plate XLI. We should notice the tunnel, leading from the outer world, through which the busy workers hurry to and fro. Between the walls of the cavity and the nest there is a space, widened at intervals to form galleries for the convenience of those wasps whose duty it is to repair and enlarge the outer cover. The only entrance to the nest proper is at its lower extremity. Through this gate hurry the workers laden with food and building materials; others, issuing, carry dead grubs and the refuse of the nest. A nest which is examined late in the season usually consists of seven combs, hanging one from the other; but the cell structure of the first or upper comb is generally cut away when the community becomes populous, so as to form a commodious hall wherein the adult wasps congregate at night and in wet weather. Apart from this the paper cells are cleaned and used again and again for rearing successive broods of grubs.

We may imagine ourselves entering the nest and mixing with the throng of workers. We shall realise at once that we have come into a topsy-turvy realm, for if we stand upon the surface of one comb and look vertically upwards, we see into the cells of the comb next above. Some of these contain eggs, others grubs in various stages of growth, while still others are closed to the eye by caps of spun silk. In these last the pupæ lie hidden. That the wasps should have chosen this head-downward method of rearing their young is very puzzling. The disadvantages are many and obvious. The rule is that the queen glues the egg to the side of the cell. When the grub hatches, it remains at first with its tail in the egg-shell, moving upon this pivot, and craning its head to the mouth of the cell to receive food from the workers. But as it grows, it must change its position in order to avail

Plate XLI



Imaginary section through a bank containing a Wasps' Nest

itself of the full accommodation which the cell affords. It has only two grasping organs, namely, its jaws and a kind of sucker foot at its tail-end; so that if it relaxes its hold at one extremity before making fast with the other, it immediately falls headlong from the cell. Such accidents are by no means rare; and one would think that a daily shower of helpless infants from the ceiling would suffice to teach the least attentive nurses that vertical cradles are unsafe. But the workers seem to accept these accidents as a matter of small moment, and rarely attempt to replace the fallen grubs. They usually carry them out, and drop them at some distance from the nest, exactly as they do with refuse.

The lucky grub which succeeds in planting its sucker foot firmly against the roof of its cell soon has nothing to fear, for it grows so fat that it completely fills its cradle. It is regularly supplied with food by its nurses, the diet consisting mainly of the softer parts of insects, varied by an occasional mouthful of nectar or fruit juice. From ten to fourteen days after hatching the grub is full-fed, spins a silken cap over the mouth of its cell, and changes to a pupa. The whole metamorphosis, from egg to perfect insect, occupies rather more than three weeks under favourable conditions of temperature. Like the hive-bee, the newly emerged adult wasp passes a period of probation within the shelter of the nest ere she goes forth to forage for the benefit of the community. When young and vigorous she is chiefly engaged in building; but ere long, probably in less than three weeks, her salivary glands become exhausted, and her powers of paper-making fail. She may now be styled an "old wasp," and devotes her remaining energy to the care of the rising generation.

A prosperous wasp colony, at the close of the summer, consists of thousands of workers, each a direct offspring of

the original queen. As autumn approaches, certain large cells are added to the lower combs. Indeed, the lowest comb of all is usually exclusively composed of these special cells, which may be termed the royal nurseries. In them a brood of princes and princesses is reared—*i.e.* males and functionally perfect females. This brood may consist of scores or hundreds of individuals according to the prosperity of the community. The amours and merry-making of these royal personages keep the nest in a state of joyous activity, for the advent of young queens is not a signal for revolt, as is the case with hive-bees. The workers go to and fro with their burdens, the grubs are cleaned and fed with due care. Yet the prescient observer knows full well that the day of the wasp is almost over—that the great kingdom is tottering to its fall. The chills of autumn will strike to the heart of this prosperous community with the terror of a pestilence. Starvation will ravage it, for the wasps have stored no emergency rations within their paper walls; and with the cold of approaching winter gnawing at their vitals they cease to roam abroad in search of food. Thus they die—die by tens, by hundreds, by thousands—the enfeebled workers actually dragging the half-grown grubs from their cells, and casting them forth to share the common fate of the community. Only the young queens survive, destined as they are to found new colonies in the year to come. After mating with a drone, each one seeks a hiding-place and passes the winter in lonely widowhood.

Wasps are attacked by numerous parasites, including the curious beetle called *Metœcus paradoxus,* which is said only to infest *Vespa vulgaris.* In the nests of *V. rufa,* a cuckoo wasp known as *V. austriaca* is sometimes found. It has no workers, and presumably foists itself upon its hosts in much the same way that the *Psithyrus* bee enters

Nest of Wood-ant (*Formica rufa*)

Nest of a Carder Humble-bee (*Bombus muscorum*), opened to show the cocoons

a humble-bees' nest. In this case, however, the welfare of the young must be the sole incentive, for there is no store of honey to pilfer.

The social habits of ants are even more complex and remarkable than those of bees and wasps. Moreover, while the communities of some species are less perfectly organised than others, solitary ants are unknown. Yet ants, as a family, do not excel in architecture. They have no specialised building material such as wax or papier-maché. Some species dwell in subterranean chambers or burrow into decaying tree stumps; others, as we have already seen, frequent the internodes or interstices of living plants; while a few take up their abode in the walls of larger ants' nests, and (like mice in our houses) live by filching the stores of their hosts.

In this country the most pretentious nests are made by the large species of the genus *Formica*, of which the common red wood-ant or "horse-ant" (*F. rufa*) is the best known example. It is especially characteristic of fir woods, where it piles up mounds of pine needles and small twigs, these accumulations surmounting a labyrinth of galleries and chambers which extends far into the ground. A wood-ant community usually comprises several egg-laying females, or queens, and many thousands of workers. The latter vary greatly in size; and, as with humble-bees, the larger individuals engage in foraging expeditions, and collect building materials, while the smaller act as nurses, and seldom leave the nest. Winged males and young queens are only found in the nest as the season of swarming approaches.

Among ants in general the caste-system is carried to extraordinary lengths. In some instances the males and females of the same species exhibit remarkable differences—some being winged and others wingless;

while many exotic ants have a specialised worker caste known as "soldiers." These, like the ordinary workers, are imperfectly developed females, but they have exceptionally large heads and mandibles. In the case of the "honey-ants," of which a number of species are known, certain of the workers sacrifice their activity in order to act as living food reservoirs. The Mexican species (*Myrmecocystus melliger*), as observed by Dr. H. C. McCook, sends out workers at night to collect the sugary exudations of a certain oak-gall. On their return, the foragers pass this substance on to other workers, which hang sluggishly from the roof of little chambers in the nest. The crops of these "honey bearers" eventually become enormously distended, so that the whole abdomen looks like a small translucent fruit. Apparently the sole object of this extraordinary habit is to preserve the food until such time as it shall be needed by the community. Very little is known as to the origin of castes among ants; but the evidence, so far as it goes, points to the conclusion that the differences are due to the quantity and kind of food which the larvæ receive from their nurses—as is known to be the case with hive-bees.

Ants excel all other animals in their devotion to the rising generation. The queens of the nest are fed and tended by the workers, and the eggs which they lay are assiduously collected and carried off. But the eggs are not kept permanently in isolated cells. They are constantly moved from one part of the nest to another, so that the most favourable conditions for their development may be secured. Still greater care is bestowed upon the larvæ. They are fed by the workers at regular intervals, cleaned, classified according to age, and carried from chamber to chamber with never-failing solicitude for their

welfare. The food of adult ants consists of nectar, fruit, the "honey-dew" secreted by aphides, caterpillars and small insects which are attacked and killed, and flesh bitten from the carcases of dead animals; the larvæ, however, are provided by the workers with predigested nourishment, or chyle. Finally, the newly formed adult ant is carefully groomed and fed in preparation for its life-work. The cocoons of ants are commonly sold as "ants' eggs" for feeding pheasants, gold fish, &c. The larvæ of some ants, however, do not spin cocoons; and Mr. Edward Saunders has pointed out that among British ants this is always the case with those species which possess stings in the adult state. But members of species which normally form cocoons occasionally omit to do so.

None of our British ants lay up stores for winter use, despite the popular belief to the contrary; the community simply retires to chambers far below the surface of the soil, and there, huddled in somnolent masses, awaits the return of warm weather. Thus, a colony of ants may persist over long periods of time. Darwin mentions that an old man of eighty told him that he had seen one very large nest of the wood-ant in the same place ever since he was a boy.

Ants are remarkably free from the attacks of true parasites, but they have very numerous associates. The mystery which often surrounds the status of these residents in the nests has led to the assumption that ants actually keep pets, just as we keep cats and dogs; but this is improbable. Many of the beetles that live with ants are known to furnish their hosts with much-coveted secretions of a sweet or aromatic nature; and in return for these luxuries the ants not only provide food and shelter, but groom their guests with as much care as

they bestow upon their own young. Certain species of beetles are never found except in association with ants. Some, such as *Claviger testaceus*, are totally blind and are incapable of feeding themselves. When deprived of ant-assistance they die, even though surrounded by food. Such cases of symbiosis, or mutual benefit, are well authenticated. On the other hand, many insects which frequent ants' nests must undoubtedly be set down as robbers. They kill and devour the ants' larvæ and pupæ, and pilfer their food. Sometimes the theft is effected in a most barefaced manner. The French entomologist Janet has described the way in which a species of "silver fish" (*Lepismina*) takes food from the very mouths of ants which are in the act of feeding one another. When workers, filled with nectar or other juices, return to the nest, they are solicited for food by those that have remained at home; and as a forager and a nurse stand face to face, the former disgorges a small drop of liquid which is seized by the latter. While a pair of ants are thus engaged, the *Lepismina* rushes in, grabs the drop, and hurries with it to a hiding-place. Needless to add, these interlopers are constantly chased by the ants from one corner of the nest to another.

The relationships which exist between ants and plant-lice or aphides are very interesting. Reference has already been made to the fact that these insects are habitually visited by ants, which feed upon their secretions; but the matter does not end here. Some ants take great care of the aphides, protecting them from the assaults of enemies, and in certain instances erecting over them sheds of mud, which are reached through covered passages. Further, ants are known to collect the eggs of aphides in the autumn and carefully preserve them in their nests throughout the winter; while in the case of the small yellow ant

(*Lasius flavus*) Lord Avebury found that when six months later the aphides hatch, they are brought out by the ants and placed upon young shoots of the daisy—their proper food.

Still more remarkable are the habits of certain ants which press other ants of different species into their service, employing them to perform the various duties which usually devolve upon the workers of the community. There are degrees of this slave-making habit, as it is called. Thus, in the case of the wood-ant *Formica sanguinea*—the only British slave-owner—occasional sallies are made upon the nests of smaller species, when desperate fights ensue. As its name implies, *F. sanguinea* is a bloodthirsty ruffian, and conducts its military operations with no little skill. The defenders of the attacked nest are usually overpowered, and the victorious raiders carry away many larvæ and pupæ. These are carefully tended; and when the adult insects appear, they become domestic drudges in the alien nest. They serve their captors faithfully, and relieve them of much irksome toil. When a colony of *F. sanguinea* changes its quarters, as sometimes happens, they carry their slaves with them. But the depraved Amazon ants (*Polyergus rufescens*) of Europe are actually carried by their slaves when concerted movements are made. Moreover, the Amazons are dependent upon their captives to an extraordinary degree, being practically incapable of feeding either themselves or their young. Yet because they are excessively fierce and warlike, they are probably never at a loss to secure as many slaves as they need. One of the most remarkable facts connected with the slave-making proclivities of ants is that the enslaved individuals make no attempt to escape, although they are free to come and go as they please. Strangest of all, however, is the case of a rare European ant called *Aner-*

gates atratulus, of which there is no worker caste. The males and females cohabit with the workers of an entirely different species, known as *Tetramorium cæspitum*. Exactly how this state of things originates has not yet been discovered, but it is supposed that a young *Anergates* female enters the nest of *Tetramorium*, destroys the rightful queen, and substitutes herself in place of the victim. If this should prove to be the case, the triumph of the alien must be comparatively short-lived, for when the workers of the *Tetramorium* community die, she must be compelled to pack or perish.

In no respect is the genius of the ant more apparent than in the organisation of its commissariat. Not only is food collected with unfailing assiduity and discrimination, but many expedients are adopted whereby a constant supply is assured. Lord Avebury mentions that certain British ants collect the seeds of violets and grasses and carefully preserve them. From some such beginning may have arisen the extraordinary habits of the agricultural, or harvesting ants, of which some twenty species are known. In Southern Italy, members of the genus *Aphænogaster* were observed by Mr. J. T. Moggridge to collect systematically the seeds of speedwell, nettle, fumitory, and other plants, as well as oat grains. Most of these were gathered from the ground; but some ants were seen to climb up the stems and detach the seeds, which they either carried away or dropped among their expectant companions below. The seeds are stored in special chambers, of which each community is said to possess about one hundred, with a capacity of 20 ounces or more. By some unexplained means, the ants prevent the seeds from sprouting until they are required for food; but when rations are needed, they allow germination to proceed, so that the store of starch in the seed is converted into sugar.

This the ants consume, having first arrested further growth by nipping off the young shoots.

The allied Texas species (*Pogonomyrmex barbatus*) is even more advanced in its methods. Paths from 60 to 300 feet in length radiate from the nest, and along these the insects go to and fro to gather their harvest. When the seeds are safely garnered, their husks are removed by the ants, and placed on a kind of midden outside the nest. Furthermore, the ants clear away all the herbage in the immediate vicinity of their nests, or formicaries, with the exception of two species of grass (*Aristida oligantha* and *A. stricta*) known as "ant rice." The seeds of these grasses are especially liked by the ants, and there is no room for doubt that they cherish the plants on this account. Dr. H. C. McCook states that: "No other plant is thus tolerated, and these seeds are gathered and stored with others in the underground granaries. Moreover, it is quite within the ants' power to keep their discs clean. They were often found established in a thicket of wild sage, daisy, and other vigorous weeds, with stalks as thick as one's thumb and standing several feet high. This rank growth, quickened by the fat soil and semi-tropical sun, is as thoroughly under the control of our Barbati as are the cleared fields amid the woods under the settlers' control. Not a plant is allowed to intrude upon the formicary bounds; and although often seen, it was an interesting sight, after pushing through the high weeds, to come upon one of these nests, and observe the tall, tough vegetation standing in a well-nigh perfect circle around the edge of the clearing. The weeds had crowded up as closely as they dared, and were held back from the forbidden ground by the insects, whose energy and skill could easily limit their bounds. Certainly, ants capable of such work could readily have cleared away growing

stalks of the Aristida. In fact, after the seed has ripened in the late summer they are said to clear away the dry stalks in order to make way for a new crop. It is this that justifies the reputation of Barbatus as a farmer. She has not been seen—as far as the writer knows—sowing the seeds, but she permits them to grow upon her formicary bounds, and afterwards utilises the product."

The most formidable foes to vegetation in Tropical America are the large Saüba or leaf-cutting ants of the genus *Atta*. They dwell in extensive subterranean nests, above which the excavated earth is piled into a mound that may be thirty or forty feet in diameter. From these strongholds the workers issue in gangs, and ascend the trees. "Each one," writes Bates, "places itself on the surface of a leaf, and cuts with its sharp scissor-like jaws a nearly semi-circular incision on the upper side; it then takes the edge in its jaws, and by a sharp jerk detaches the piece. Sometimes they let the leaf drop to the ground, where a little heap accumulates, until carried off by another relay of workers; but, generally, each marches off with the piece it has operated upon, and as all take the same road to their colony, the path they follow becomes in a short time smooth and bare, looking like the impression of a cart-wheel through the herbage." Along these roads workers stream to and fro, and their energy is such that they are capable of stripping a tree of its leaves in a few hours. The use that these ants make of the enormous bulk of material which they accumulate in their habitations was for long a matter of speculation, but Belt discovered that the original pieces of leaf were cut into tiny fragments and piled up to form spongy-looking masses within the chambers of the nest; also that these masses become clothed with a minute white fungus, upon which the ants appeared to feed. It remained for the German

naturalist Möller to investigate the matter so thoroughly as to leave no room for doubt. His discoveries have been briefly summarised by Dr. Sharp as follows: "This fungus (*Rozites gongylophora*) the ants cultivate in the most skilful manner: they manage to keep it clear from mouldiness and bacterial agents, and to make it produce a modified form of growth in the shape of little white masses, each one formed by an agglomeration of swellings of the mycelium. These form the chief food of the colony. Möller ascertained by experiment that the results were due to a true cultivation on the part of the ants: when they were taken away from the nests, the mycelium produced two kinds of conidia instead of the ant-food." It has been discovered recently that the young queen leaf-cutting ants, when they leave the nest for the nuptial flight, carry in the mouth small quantities of the *Rozites* fungus, doubtless for the purpose of starting fresh cultures when new nests are formed.

The popular term "white ants," as applied to termites, is a regrettable misnomer—no two divisions of insects being more distinct than the true ants and the so-called white ants. The former are insect aristocrats; the latter are not very far removed from the most primitive types. Thus, the fact that the two groups should display much the same kind of social organisation is very remarkable. We have seen that the social life of ants, bees, and wasps hinges upon the helplessness of the young—each community being a huge co-operative nursing establishment; but the case of the termite appears not to admit of a like explanation. The young emerge from the eggs as active, six-legged creatures which call for no specialised fostering. They certainly receive food from the older members of their community, and are carefully groomed by them when occasion demands; but these attentions seem to

be the effect of cohabitation rather than its determining cause, for adult termites habitually pass on food to their kindred, old and young alike, while there is a constant interchange of courtesies within the nest. We must assume, therefore, that a desire for companionship, coupled with an instinctive appreciation of the advantages which arise from combined action in the fields of labour and of war, are the factors which have called termite communities into being. In other words, they probably represent an extreme elaboration of the gregarious habit which obtains among locusts and caterpillars.

Termites inhabit the warmer regions of the globe, and attain their zenith of power and prosperity in the tropics, only two European species being known. The population of a termitarium (*i.e.* a community or state of termites) varies from a few hundred in some species to millions—it may be hundreds of millions—in others. The castes are always strongly marked, and a given nest may comprise a bewildering variety of forms. But there are always two sharply distinguished general classes, to wit, the propagators and the workers. The latter frequently include a number of individuals (easily distinguished by the great size of their heads and jaws) which are termed "soldiers." These are popularly supposed to defend the nest, yet the gravest suspicions have been cast upon their ability to perform this office, for they are not really such effective combatants as the workers. With their unwieldy jaws they are unable to gnaw wood, or to eat the usual kinds of termite food. Thus, they are condemned (at least in the case of one species) to long periods of starvation, broken at intervals by cannibal orgies. Not only do they devour their dead companions and kill off the sick and maimed, but in times of excitement they are seized with a kind of mania, and destroy five or six of their fellows

with a few blind strokes of their huge jaws, incidentally providing themselves with a hearty meal. Yet they decline to eat the dead of alien tribes that have been slain in battle. In a word, these so-called soldiers seem to impose upon, rather than to protect, their community, and one marvels that they should be tolerated within its walls.

The propagating class among termites consists mainly of individuals which are winged when they reach maturity. At a certain season of the year these young kings and queens are produced by thousands, and on a given day they all leave the nest. Most of them are snapped up by birds, reptiles, and other insectivorous creatures, but a few escape and go off in pairs to found new colonies. It is a curious fact that immediately they reach the ground after this flight these insects tear off their own wings—a feat that is rendered easy by the suture, or line of weakness, which occurs in each wing near its base. The wingless king is not an imposing personage; but before her reign is far advanced, the queen develops in a most extraordinary manner. In the case of the West African warrior termite (*Termes bellicosus*) her enormous abdomen may weigh eventually 1500 or 2000 times as much as the rest of her body, while she may produce as many as sixty eggs per minute. In a word, she becomes a vast egg-laying machine, helpless and inert. The queen and her consort dwell within a special royal chamber at the very heart of the termitarium. "I once succeeded," writes Professor K. Escherich, "in extracting the royal chamber from a nest of the African warlike termite, and examining it through an incision, just large enough to admit sufficient light to make the interior visible without disturbing the inmates, I beheld a very animated and interesting scene. In the background lay the enormous white queen, three inches long, and so

thick that she was pressed tightly between the floor and the ceiling. She was motionless, except for a series of waves moving rearward along her swollen abdomen. By her side stood the king, a dwarf compared with his mate, in a very remarkable posture, with his long legs widely separated, his head down, and his tailed cocked upward. Now and then he pressed against his consort's side or tried to crawl under her. The royal pair were surrounded by hundreds of small workers, some running round as if in a circus, others reaching out from floor and ceiling to brush and lick the king and queen. The queen's head, thorax, and legs were covered with little workers, busily grooming and feeding her. At the opposite end of her body the scene was still livelier. At intervals of from one to three seconds a tiny, long-oval egg issued from the tip of the abdomen and was immediately seized by a worker, cleaned, and carried away to one of the surrounding egg-chambers. These operations were performed with a regularity that suggested the work of a factory. When we consider that a termite queen probably lives ten years or longer, and devotes at least half her life to egg-laying, we can form some idea of her prodigious fertility and of the number of her subjects."

The numerous castes which make up a termite community are indistinguishable when they first leave the egg. Moreover, the workers and soldiers are not all imperfectly developed females, as is the case with social Hymenopterous insects, but comprise individuals of both sexes. Termites are able to modify, check, or accelerate the development of their young. Probably this power consists mainly in a judicious administration of food; but it has still to be shown that these amazing insects do not practise a mysterious system of massage or surgery. It is at least probable that young individuals which promise

to turn out unsatisfactorily are killed and eaten by their nurses. Be this as it may, the fact remains that from eggs which are apparently identical termites can produce at will royalties, workers, soldiers, or any of the intermediate forms which are found in the nest. Moreover, the development of some females of the special sexual forms is arrested, so that they neither produce wings nor join in the swarming exodus; but they are held in reserve in case the reigning queen of the nest should die, when one of them is promoted to take her place. These individuals have been called "complementary reserve queens," and, when actually substituted for a queen, "substitution queens." Male insects, or kings, appear to be reserved in the same way.

Some termites are far less advanced in their social organisation than others. The yellow-necked species (*Calotermes flavicollis*) of the Mediterranean littoral is, according to Dr. Sharp, "a representative of a large series of species in which the peculiarities of termite life are exhibited in a comparatively simple manner. There is no special caste of workers; consequently such work as is done is carried on by other members of the community, viz. soldiers and the young and adolescent. . . . The king and queen move about, and their family increases but slowly. After fifteen months of their union they may be surrounded by fifteen or twenty young; in another twelve months the number may have increased to fifty, and by the time it has reached some five hundred or upward the increase ceases. This is due to the fact that the fertility of the queen is at first progressive, but ceases to be so. A queen three or four years old produces at the time of maximum production four to six eggs a day. When the community is small—during its first two years—the winged individuals that depart from it are about eight

or ten annually, but the numbers of the swarm augment with the increase of the population."

Termites also differ widely in the character of their habitations. Some species, such as the yellow-necked termite above referred to, dwell within the decayed stumps and branches of trees, and their greatest architectural triumphs consist in a few barriers thrown across the natural hollows of the wood. Others rear structures so enormous that they profoundly modify the appearance of the tropical landscape. The warlike termite builds conical hills, which sometimes attain a height of from 6 to 10 feet, while the towers of certain Australian species occasionally reach a height of 23 feet. The latter structures are very slender, and are supported with pilasters. Another Australian termite, nicknamed by the officers and men of H.M.S. *Penguin* the "compass ant," sets up inverted, wedge-shaped masses of dark grey mud, from 4 to 5 feet high, which look like so many tombstones in a churchyard. The strangest point about these erections, however, is the fact that they have invariably the same orientation—the long faces of the wedge pointing nearly north and south. Many species of termite build hanging nests among the branches of trees; but these are usually, if not invariably, connected by covered passages with subterranean galleries and chambers.

Termites almost always approach the object of their desire through tunnels, and are scarcely ever seen in the open, although they roam over a wide area, and ascend to the topmost branches of tall trees. Professor Drummond gives the following description of the manner in which these insects work: "At the foot of a tree the tiniest hole cautiously opens in the ground close to the bark. A small head appears with a grain of earth clasped in its jaws. Against the tree trunk this earth grain is

deposited, and the head is withdrawn. Presently it reappears with another grain of earth; this is laid beside the first, rammed tight against it, and again the builder descends under ground for more. The third grain is not placed against the tree, but against the former grain; a fourth, a fifth, and a sixth follow, and the plan of the foundation begins to suggest itself as soon as these are in position. The stones, or grains, or pellets of earth are arranged in a semicircular wall, the termite, now assisted by three or four others, standing in the middle between the sheltering wall and the tree, and working briskly with head and mandibles to strengthen the position. The wall, in fact, forms a small moon-rampart, and as it grows higher and higher, it soon becomes evident that it is going to grow from a low battlement into a long perpendicular tunnel, running up the side of the tree." The building material employed by termites may be either earth or wood, very finely triturated, and mixed with cement-like secretions from the insects' mouths. When this composition solidifies, it attains such an astonishing hardness that the large termitariums can only be opened by means of gunpowder and dynamite.

So far as is known, the internal arrangements are similar in all large nests. The royal apartment occupies a central position, and is surrounded by a series of concentric shells, each containing many chambers. Most of the domed nests are divided into several stories, and are connected with underground galleries, which often extend to a distance of several hundred feet. The wood, and possibly the earth, that is employed for building purposes appears always to be swallowed before being used—a procedure which ensures thorough grinding and amalgamation, as well as the extraction of any contained nutriment. Termites are frugal to a fault. Not only do they subject

their very building materials to a digestive process, but they actually eat the same food over and over again, and maintain a spotless cleanliness in their habitations by the simple process of devouring all refuse matter, including the cast skins of their young. There can be little doubt that these strange habits are due to the fact that the termites' staple article of diet—*i.e.* dead wood—is poor in nitrogen, and difficult to digest. There is no margin for waste or for neglecting any opportunity to feed. In this connection it is interesting to note that certain species of termites, like the South American leaf-cutting ants, grow a kind of fungus. The workers heap up spongy, yellowish masses of wood pulp in the larger apartments of the nest; and these masses soon become plentifully sprinkled with a small, white fungoid growth of a peculiar kind, apparently induced by termite cultivation. The fungus extracts from the wood pulp its nitrogenous matter, and the insects thus secure a supply of concentrated food, which is said to be employed chiefly for nourishing the younger members of the community. When a portion of prepared wood pulp, or "mushroom cake," as it has been called, becomes exhausted, it is removed, and replaced by a fresh supply. The workers of one African species of termite have been observed to issue from the nest at high noon to cut and carry pieces of grass and leaves, and there can be little doubt that this material is also employed for fungus-growing. These workers, as well as their companion soldiers, have faceted eyes; whereas in most other species all but the royal castes are quite blind. Some termites actually feed upon the secretions of their own salivary glands, or those of their companions. A tiny globule of liquid appears in the mouth, and when it has increased to about one millimetre in diameter, it is either swallowed, used for building purposes, or—if the termite

be neither hungry nor in the mood for work—passed on as a dainty to another individual.

More than one species of termite may cohabit in a single nest, which may also afford shelter for numerous other animals, chiefly insects. Many of the latter are strangely modified in structure—the result probably of long-continued symbiosis, and of participation in the termite diet; but whether the rightful owners of the termitarium derive any benefit from the presence of these guests has not yet been discovered. Indeed, the economy of termites is still very imperfectly understood, and offers a wide field to investigators of the future.

CHAPTER XVIII

INSECTS IN THE WATER

Although insects are essentially creatures of the earth and air, many species have adopted an aquatic life. Yet no hard-and-fast line can be drawn between water insects and their terrestrial kindred, for many larvæ feed habitually in semi-liquid mire, or in water-logged soil, while large numbers of insects, notably beetles, frequent marshy spots, and are equally at home upon land or in the water.

So far as is known, no insect remains submerged throughout the whole of its life. Numerous bugs (Heteroptera) frequent water in all the stages of their existence, but they breathe atmospheric air, and drown quickly if they are kept forcibly below the surface. Many of them—*e.g.* the water boatmen (*Notonectidæ*)—have well-developed wings in the adult state, and fly freely from one pond or lake to another, especially after nightfall. The familiar pond-skaters and their allies (*Hydrometridæ*), which glide over the surface of stagnant pools and sluggish streams, make frequent excursions among the herbage of the banks. Indeed, they really walk upon the water—or rather upon the elastic surface-film where air and water meet. Their body and legs are covered with minute hairs, which tend to retard moisture; and they may frequently be seen lifting their legs into the air to dry them. If their feet become wet, they sink through the surface-film.

Another interesting group of surface-dwellers consists of the whirligig beetles (*Gyrinidæ*), whose middle and

Water-beetle (*Dytiscus marginalis*) in the act of taking breath

Water-beetle (*Dytiscus*) compared with typical Ground-beetle (*Calosoma*)

hind pairs of legs are paddle-like. They spend most of their time skimming over the surface-film, but dive rapidly when danger threatens. Their larvæ are continually submerged, but when full grown they creep up the stem of a water plant, upon which they spin their small, oval cocoons.

The best-known water-beetles, however, are the *Dytiscidæ*, typified by the common diving beetle (*Dytiscus marginalis*). This insect's body is oval, somewhat flattened, with a highly polished surface, while the various parts are so closely adjusted as to present practically a continuous outline. The great hind-legs are modified to form a pair of oars, which—by a peculiar keel-like prolongation of the thorax—are set far back, below the centre of the insect. This arrangement, and their articulation, enable these limbs to be brought at right angles to the body, thus providing for a strong, wide sweep. Moreover, the joints of the tarsi are flattened and clothed with stiff hairs, so that these organs are transformed into perfect reciprocating oar-blades. Normally, they strike the water simultaneously; but they can be used singly for the purpose of turning in a confined space, just as an expert sculler will use one oar to manœuvre his skiff. Thus, while the broad structural features of *Dytiscus* agree with those of its near relations, the carnivorous ground-beetles (*Carabidæ*), they are beautifully adapted to meet the requirements of an aquatic life. Indeed, no other insects are equipped for so wide a sphere of existence as these large water-beetles. They are certainly clumsy pedestrians, but their broad wings enable them to make long voyages in the air; and if one pool or stream is not to their liking, they quit it at night, and range over the countryside in search of more congenial quarters. The rapacious larvæ are often called "water tigers." They

have grooved mandibles, somewhat like those of the ant-lion, and suck the juices of their victims. When full-fed they leave the water, and form cells in the earth, where they change to pupæ.

The chief problem which confronts an aquatic insect is that of obtaining the supply of oxygen necessary for its vital processes. We know that the typical insect breathes by means of tracheæ, which communicate with the atmosphere through openings called spiracles; but it is obvious that this plan could not succeed under water without considerable modification. The variety of ways in which the difficulty has been surmounted is extremely interesting. In *Dytiscus* the spiracles are not placed along the sides of the body, as is the case with most terrestrial insects, but open upon the back, beneath the elytra. Moreover, the two posterior pairs of spiracles are unusually large; and the elytra fit perfectly against the abdomen, so that an air-tight space is formed between them and the insect's back. When the beetle desires to take breath, it poises itself in the water, thrusts its tail-end through the surface-film, and slightly depresses the tip of its abdomen, with the result that air rushes into the four large spiracles, and fills the space between the elytra and the back. The chink is then closed tightly, and the insect is once more ready for a diving excursion. Dr. Sharp tells us that the male *Dytiscus* rises to the surface to take breath once in every eight minutes and twenty seconds on an average, and remains poised for about fifty-four seconds. The longest interval that the insect was observed to pass without rising to the surface was nineteen minutes, although the female, being less active in habit, rises less frequently than her mate.

The whirligig beetles dive to escape danger, but do not stay long beneath the surface. They carry with

them a small bubble of air. The film which encloses this stretches from the tip of the wing-cases to the hinder end of the abdomen. Many other aquatic beetles and bugs have their bodies covered wholly or in part with fine, velvety hairs, which entangle sufficient air for the tracheæ to perform their function while the insect is submerged. The water-skaters are hairy all over; and when they dive, they are completely surrounded by an air-bubble. But the great black water-beetle (*Hydrophilus piceus*) is downy only on the under surface of its body, and when submerged carries its air-supply like a silvery breastplate. The manner in which this insect replenishes its store of air without leaving the water is very remarkable. The terminal joints of its antennæ are broad and hairy, and serve as little ladles, by means of which small air-bubbles are dragged down and added to the supply beneath the body.

In the larva of *Dytiscus* all but the last two spiracles at the extremity of the abdomen are obsolete; and when the insect requires a fresh supply of oxygen, it rises to the surface, and thrusts the tip of its tail into the atmosphere. Among water scorpions and their allies (*Nepidæ*) a similar arrangement is in force; but the body terminates in a pair of grooved appendages, which can be pressed closely together so as to form a long tube, through which air is conveyed to the spiracles. The larva of a gnat is also furnished with a breathing tube, which springs from the last segment but two of the abdomen; while the pupa has two trumpet-like tubes on the prothorax. But the most extraordinary respiratory appendage of this kind is possessed by the so-called "rat-tailed" maggots. These are the larvæ of the drone-fly (*Eristalis tenax*). They feed in liquid filth, or shallow pools of stagnant water, and have long telescopic "tails," that can be

extended to a distance of several inches. By this means the submerged larva secures a supply of oxygen, for the tube contains two tracheæ, which lead to spiracles; while if the liquid in which the larva lies becomes deeper, owing to a sudden shower of rain, the tube can be lengthened accordingly.

All the insects which have so far been mentioned drown quickly if they are forced to remain under water for more than a limited period of time. They are equipped, as it were, with a more or less perfect diving apparatus; but they are entirely dependent upon atmospheric air. There are other insects, however, which can remain below indefinitely, for they are able to utilise "dissolved air"—*i.e.* the air which is mixed with water. In the very young nymphs of many species, such as may-flies and some dragon-flies, aeration of the blood is effected through the skin. But as growth proceeds, specialised gills are frequently developed. These are very diverse in form and situation, but in general terms they may be described as thin-walled outgrowths of the integuments containing delicate branches of the tracheal system. More rarely the gills contain only blood. By a process which is at present imperfectly understood, these organs extract oxygen from the water. The larvæ of whirligig beetles, of alder-flies, and the nymphs of may-flies have branching or leaf-like gills at the sides of the abdominal segments. Other species carry their gills like tails at the end of the body. But in certain of the large dragon-fly nymphs the gills occupy the posterior part of the alimentary canal, into which water is drawn and expelled by a gentle pulsation of the abdomen. When alarmed, these nymphs can eject the water with such force that their bodies are propelled swiftly forward. Other dragon-fly nymphs possess exposed tracheal gills at the tail-end of the body.

During the latter stages of their development, however, the thoracic spiracles of all dragon-fly nymphs are open, and the insect obtains at least some of its oxygen by raising the front part of its body above the surface of the water. "These various adaptations to an aquatic life in a single group" (writes Professor Carpenter) "indicate clearly that the habit of living in water is not primitive among insects, but that it has become acquired by different races at different times in the course of development. It may be presumed that larvæ with the more perfect adaptations for breathing when submerged—leaf-like or thread-like gills—are older inhabitants of the water than those which have to rise periodically to the surface to take in a supply of air." Gill structures always disappear with the last moult, except in the case of stone-flies (*Plecoptera*), some of which retain their gills in the adult state. To what extent the organs retain their original function is not known; but the fact that they persist is very remarkable, and suggests that the aquatic habit of stone-flies may be of very ancient origin, going back to a time when the atmosphere was much more heavily charged with moisture than is the case to-day. Indeed, the fossil remains of gill-bearing adult insects, possibly ancestors of existing stone-flies, have been found in rocks belonging to the immensely remote carboniferous period.

Passing reference has already been made to the larvæ of certain midges (*Chironomidæ*) which are known popularly as "blood-worms." They are of unique interest, because their blood and our own contains the same kind of colouring matter. This substance, called hæmoglobin, has the power of forming what is termed a "loose combination" with oxygen, so that the latter can be surrendered to the tissues of the body without chemical

decomposition. All these larvæ dwell in mud at the bottom of water, sometimes at a very great depth, and there can be no doubt that their red blood enables them to profit to the utmost by the very scanty supply of oxygen which their environment provides. It is interesting to note that there is another type of larva in this midge family which lives at the surface of the water. Its blood is colourless, while the tracheal system, although closed, is more perfectly developed than in the "bloodworm." Moreover, while the pupa of the latter, which only comes up through the water just before the perfect insect emerges, is provided with long gill-filaments, that of the other type has a pair of breathing trumpets (as in the gnat), and floats at the surface.

The larvæ of the pretty river-side beetles which constitute the genus *Donacia* (family *Chrysomelidæ*) live on the submerged roots of aquatic plants. They are provided with two sharp, tubular processes near the extremity of the body, which they drive into air-spaces in the plant tissue, and extract sufficient oxygen for their needs. They thus derive both food and air from the plants with which they are associated.

It must not be supposed that the foregoing examples exhaust the list of devices by means of which submerged insects breathe. The fact is that while something is known of this subject, much remains to be discovered. As Professor F. W. Gamble has said, "It is probable that the larval histories of insects will yield many interesting additional facts to the known means of respiration, for many flies which require an ample supply of atmosphere when winged, pass their larval life in surroundings that are almost without oxygen—for example, as parasites in the stomach of the horse (*Gastrophilus equi*), in wood of trees, and the fleshy substance of nuts, galls, &c."

Plate XLIV

Common May-fly (*Ephemera vulgata*)

Larva of Water-beetle (*Dytiscus marginalis*

Nymphal skin of a Dragon-fly (*Æschna*)

Water Boatman (*Notonecta glauca*)

Water Scorpion (*Nepa cinerea*)

If we attempt a rough classification of water insects, we obtain the following table:

Plecoptera (Stone-flies) *Ephemeroptera* (May-flies) *Odonata* (Dragon-flies) *Trichoptera* (Caddis-flies)	Stages preceding the imago always aquatic; breathing dissolved air cutaneously or by means of gills.
Neuroptera . . .	Larva aquatic in one family—viz. the alder-flies (*Sialidæ*); breathing dissolved air by means of gills; but pupa terrestrial.
Hemiptera . . .	About one-third of the bugs (sub-order Heteroptera) are more or less aquatic in all stages; breathing atmospheric air.
Coleoptera . . .	About one-tenth of the beetles frequent water in one stage or another; some aquatic in all stages; breathing atmospheric air or (rarely) dissolved air by means of gills (e.g. *Gyrinus* larva); pupa usually terrestrial.
Diptera	Less than a quarter of the two-winged flies are aquatic in stages preceding the imago; breathing atmospheric air or dissolved air cutaneously or by means of gills.

In addition to the above, the larvæ of a very few moths are aquatic. Some of them possess gills, while others appear to obtain their supply of oxygen through the skin. Among the latter, the caterpillar of the brown china-marks moth (*Hydrocampa nymphæata*) may be mentioned. It is often very common in ponds, where it feeds upon the floating leaves of water-lilies and other plants. The female moths creep into the water to oviposit. At first the young larva burrows into the substance of the leaf, but in later life it constructs a case, using two oval pieces of leaf fixed together with silk. By some means, not perfectly understood, the caterpillar contrives to keep the interior of its dwelling dry, so that it now lives in air, although immersed in water, and breathes in the ordinary way by means of open spiracles.

We have already seen that some of the spring-tails

(Collembola) disport themselves on the surface of the water, both fresh and salt, and that at least one species can remain submerged for weeks together. The most remarkable of all water-frequenting insects, however, are found among the Hymenoptera. One ichneumon (*Agriotypus armatus*) goes under water, and remains there for a considerable period, in order to lay her eggs in caddis-worms. The parasite larva lives inside the case of its host, and ultimately spins its cocoon there. In what manner its respiration is effected remains a mystery. Further, in the Proctotrypid sub-family *Mymarinæ* (the members are sometimes called "fairy-flies" on account of their extreme daintiness and minuteness) we have a little group of species which enter the water and lay their eggs within the eggs of aquatic insects. Most of them employ their legs for swimming, but at least one species (*Caraphractus cinctus*—often termed *Polynema natans*) actually uses its wings. It flies under water! This insect was first observed, in 1863, by Lord Avebury; but its life-history has more recently been investigated by Mr. Fred Enock. The eggs are believed to be laid in those of a dragon-fly. According to Sir Ray Lankester, these minute egg-wasps have no tracheal system, but the manner in which their tissues are aerated is apparently unknown.

CHAPTER XIX

MANKIND AND THE INSECT

WHETHER the world was made for man, or man is merely the paramount species in the great concourse of animate beings, is a riddle which has not yet been solved. But there can be no question that for practical purposes man is, and knows himself to be, the "hub of the universe." Thus, to most minds, the chief fascination of entomology consists in the light which is cast upon the relationship of insects to mankind. In the foregoing pages passing references have been made to the damage done by insects to cultivated plants; but it is scarcely possible to exaggerate the seriousness of these depredations. The statement has been made that at least ten per cent. of every crop is lost through the attacks of insects, this toll being so constant that it escapes observation; while when a particular species of pest-insect gains a temporary ascendancy, it not uncommonly sweeps everything before it. One authority has said that it cost American farmers a larger sum to feed their insect foes than is expended to maintain the whole system of education in the States. In Britain we are less sorely harassed, not from any special dispensation, but because, in the nature of things, insects are more prone to increase beyond bounds in great continental areas than on small islands. Nevertheless, our losses are often very serious.

Every kind of crop is liable to attack, often by many kinds of insects; and a given species usually does mischief in a characteristic way. This point may be illustrated by the life-histories of four pests which from time to time

prove very injurious to cereals. On Plate XLV is reproduced a photograph of five wheat ears gathered by the writer from one crop in the month of July. The first is a normal ear of average fruitfulness. The second is from a plant attacked by the ribbon-footed corn-fly (*Chlorops tæniopus*). This insect belongs to a family of little flies allied to the *Anthomyidæ*, one of its near relatives being the infamous frit fly (*Oscinis frit*), which often works havoc in oat fields. The female *Chlorops* lays her egg upon the leaves which serve as a sheath for the forming ear. When the larva hatches, it bores through these leaves, and takes up a position at the base of the ear, where it feeds upon the sap. Ultimately it eats a furrow down the stem to the uppermost joint, or knot, where it assumes the pupa state. As a result, the plant is more or less seriously stunted, the ear being checked in its development, and usually failing to emerge from the sheathing leaves. Farmers call such plants "gouty"; and *Chlorops tæniopus* is often referred to as the "gout fly." It attacks barley as well as wheat, and is sometimes the cause of very serious loss.

The third ear in the photograph was taken from a plant which had nourished a larva of the corn saw-fly (*Cephus pygmæus*). In June the female inserts a single egg into the stem, just below the first or lowest knot, and the larva, when hatched, eats its way steadily upward, often boring through all the knots. When full-fed, however, it descends the stem, and spins its cocoon close to the roots. The ears of attacked plants have a bleached appearance, stand more or less erect, and contain few if any perfect grains. Finally, the whole plant is felled to the ground by the larva, which partially cuts through the stem prior to spinning its cocoon—though what induces this apparently wanton act is not known. The corn

saw-fly has been guilty of very great injury to crops on the Continent, but so far its depredations in Britain have been relatively slight.

The fourth and fifth ears in the photograph illustrate respectively the conditions which follow attack by the Hessian fly (*Cecidomyia destructor*) and the wheat midge (*C. tritici*). Both these insects belong to the gall-midge family (*Cecidomyidæ*); but, as it happens, neither of them gives rise to a gall. The first is supposed to have been introduced into America in fodder brought over by the Hessian troops during the war of the revolution—whence its popular name. The eggs are laid on the leaves of the cereal (usually wheat, barley, or rye) in May and June. The minute larvæ work their way beneath the leaf-sheath and stem of the plant—a favourite point being just above the first or second knot. Here they feed upon the sap, either singly or several in company, and eventually pass into the pupa state—the puparium being brown in colour and almost exactly like a flax seed in shape and size. The damage to the plant is very serious. The ear becomes stunted, and the stem—weakened by loss of sap—bends over just where the larvæ are located. The Hessian fly has been responsible for incalculable loss both in Europe and America, but it has not caused serious damage in Britain since 1887. Indeed, there are those who believe it to be practically extinct in this country; but this is a mistake, as farmers may one day find to their cost.

Like the Hessian fly, the wheat midge is also known in both hemispheres. The female lays her eggs in the florets of the cereal, and the minute larvæ ("red maggots") feed upon the developing grains. Sometimes the ears are so badly infested that a loss equal to one-half of the crop results.

Other insects, too numerous to mention, attack wheat in all stages of its growth ; nor is the corn safe when it has been harvested, for many other species feed upon it in granaries, mills and ships. Among the latter the most harmful are probably the grain weevils of the genus *Calandra*. Cargoes of wheat and barley, valued at many thousands of pounds, have been rendered almost worthless during the course of a voyage through the ravages of these pests.

Almost all kinds of stored goods which contain nourishment in any form are liable to the attacks of insects. Tobacco, for instance, is greatly relished by a small beetle (*Lasioderma testacea*) and its grubs ; while wine corks are burrowed into by the caterpillars of a tiny moth, with the result that the wine becomes tainted. Later, the cork may be so much riddled that the wine escapes—the loss caused by the leakage being the so-called "ullage" of wine. Certain wood-boring beetles and their grubs tunnel into our furniture, while half a dozen kinds of caterpillars feed upon furs, feathers, clothing, and tapestry. Even the contents of the chemist's shop is not exempt ; for the so-called "paste" beetle (*Anobium paniceum*) feeds greedily upon such substances as dried capsicum and ginger. This insect is very common in factories and stores, where it does much mischief. In one instance it practically destroyed a stock of boots and shoes. Paste had been used to fasten the linings and leather together, and in devouring their favourite dainty (*i.e.* the paste) the beetles had perforated and damaged the leather, reducing it literally to rags. This happened in South Africa ; but reports of similar damage have been received from manufacturers in England.

Termites, or "white ants," rank among the most formidable pests in tropical countries. Only iron and the

hardest stone appear to daunt them. It is even said that they can injure glass by the aid of their corrosive saliva. Years ago a species of termite was accidentally introduced into the island of St. Helena—in what manner is not definitely known. It increased and multiplied to such an extent that Jamestown was soon reduced virtually to ruins, and new buildings had to be erected. In like manner termites destroyed the Governor's palace at Calcutta, and an English ship lying in Bombay harbour. Wherever they pass they leave a trail of devastation. Clothing, books, flour, and grain are quickly devoured, while woodwork is rapidly reduced to a heap of powder and chips.

The various insect assailants of domestic animals are a constant source of annoyance and loss. Gad-flies persecute horses and cattle, and are believed in some instances to infect them with disease. The bot-flies (*Œstridæ*), as we have seen, are actual parasites in their larval state, feeding in the nasal passages, the stomach, or beneath the skin of the host. The most serious are the warble-flies (*Hypoderma*), which not only detract from the quality of the beef, but also damage the hide by perforation. The late Miss Ormerod estimated the loss in Great Britain from these insects at £700,000 per annum in some years; and although this figure has now been much reduced, owing to the measures adopted by farmers and graziers, it is still very considerable.

The most serious indictment made by science against insects is that many species are active agents in the dissemination of disease. Within the last fifty years, it has been discovered that many diseases are caused by microscopic parasites; some, such as plague and typhoid fever, by extremely minute vegetables known as bacteria; others, such as malaria and sleeping sickness, by almost

equally minute unicellular animals of the class Protozoa—these parasites, by living and multiplying in the blood or tissues of men and animals, giving rise to characteristic symptoms. Still more recently it has been proved that disease "germs," or microbes, may be carried from one host to another by blood-sucking creatures of various kinds; and that in some instances the microbe actually requires two different hosts for the completion of its life-cycle. The sexual generation usually exists in an insect or other invertebrate, and the asexual generation in a vertebrate. The enormous importance of these facts in regard to mankind was first established by Major Ronald Ross, who (in 1897) definitely traced in the stomach of a mosquito the malaria parasite (discovered in human blood by the French army surgeon Laveran in 1880), and two years later worked out its complete life-history. Ross's discoveries were subsequently confirmed by others, notably by Professor Grassi, of Rome.

Briefly stated, the life-cycle of the malaria parasite is as follows: Excessively minute needle-shaped bodies are introduced into human blood with the saliva of a mosquito. Each of these penetrates a red corpuscle, upon the contents of which it feeds, and wherein it undergoes a definite development—the original needle-shaped body multiplying into a number of separate cells, or spores, as they are called. Eventually the wall of the corpuscle bursts, and all these spores, together with the waste products that have accumulated as a result of the digestive process which has been proceeding, are liberated into the blood-plasm—*i.e.* the colourless liquid in which the corpuscles float. It is this destruction of the corpuscles, and the production of waste and poisonous substances, which are the actual cause of malarial fever; and as each newly formed spore attacks a new red corpuscle, and rapidly

repeats the process of feeding, growth and spore-formation, the patient soon becomes greatly enfeebled. It is known, too, that the recurrence of chills and fevers is simultaneous with the successive generations of spores (together with the poisonous waste products) which are discharged into the blood. Quinine regularly administered kills the parasites; but they are very difficult to eradicate, and may remain in the blood for years, causing intermittent fever. Nevertheless, the process of asexual reproduction cannot go on indefinitely. A time comes when the disease exhausts itself, and spore reproduction ceases. Rejuvenation is possible, but only as the result of sexual conjugation; and for some inscrutable reason this cannot be effected in human blood. This fact was suspected prior to Ross's epoch-marking discovery, for other observers (notably Sir Patrick Manson) had worked out the life-cycle of another parasite in the blood of birds, which is sucked up by certain kinds of gnats, in whose bodies its sexual stage is passed. Indeed, it was a suggestion made by Manson that the "intermediate host" of the malaria parasite might prove to be a gnat or mosquito (the terms being synonymous) which first induced Ross to enter upon his investigations. He first experimented with common grey gnats of the genus *Culex;* but he found that the parasites sucked up by them with the blood of malarious patients were simply destroyed and digested in the insect's stomach. After some difficulty and delay, he proceeded to experiment with gnats (or mosquitoes) of a different kind—members of the genus *Anopheles;* and with these he was successful.

It has since been shown that throughout the world these particular gnats of the genus *Anopheles* are indispensable for the incubation and spread of the malaria parasite. What really happens may be briefly summed

up. Many of the parasites in human blood continue to feed and multiply at the expense of the red corpuscles; but some of them, after entering corpuscles, do not split up into spores. They become crescent-shaped, and lie dormant. If corpuscles which contain parasites in this condition are sucked up by the right kind of gnat, the crescents continue their development in the insect's stomach—becoming male and female elements. After fertilisation, the females—originally one-thousandth of an inch in diameter—swell up until they are just visible to the naked eye as minute specks embedded in the wall of the gnat's stomach. Ultimately each female, or "sphere," as she may now be called, bursts open and liberates many thousands of the minute needle-like young, which make their way through the insect's blood to its salivary glands. Thence, when the *Anopheles* bites a man, they pour down through the ducts with the saliva, and thus gain access to the blood of a new victim.

When once these facts were established, it became clear that in order to combat malaria war must be declared against mosquitoes. These insects must be prevented from biting (1) healthy humanity to whom they are likely to convey infection, and (2) malaria-stricken patients from whom they will derive fresh relays of the parasite. As the *Anopheles* mosquitoes feed chiefly in the evening, or at night, insect-proof houses or beds secure immunity. But the chief aim in malaria-infested countries is to exterminate mosquitoes by destroying their breeding places—draining swamps, and filling up small pools and puddles. If for any reason draining is impracticable, the surface of the water is covered with a thin film of petroleum. This kills any larvæ which may be present when they come up to breathe; while the adult females, which come to the water to lay their eggs, are also destroyed.

Since these discoveries were made, other insects have been shown to be alternate hosts of certain diseases which, in the past, have caused untold suffering and loss of life. A gnat or mosquito called *Stegomyia calopus* is in this way associated with the deadly yellow fever, or "Black Jack," which is endemial on the east coast of tropical America, and is often carried to sub-tropical, sometimes even to temperate zones, where—if the *Stegomyia* mosquito is present—it may rage until frosts set in. The yellow fever microbe is known to remain twelve days in the insect before it can be passed on; and during this interval it presumably undergoes certain necessary changes. But the parasite has not yet been identified, although diligent search has been made. Probably it is too small to be seen through any existing microscope. Nevertheless, experiments have proved beyond question that the germ or virus is taken up by the *Stegomyia,* and that after the twelve-days interval the insect, by its bite, is capable of infecting a healthy human being with the terrible pestilence. By recognising this fact, and by adopting measures for keeping the disease-carrying gnat at bay, yellow fever has been entirely abolished in many tropical cities within the last ten years. Moreover, the assured success of that great enterprise, the building of the Panama Canal, is chiefly due to man's new-found power to combat disease. When the French essayed the work, the mortality from yellow fever was appalling; but thanks to the advance of science the Americans have been able to override this obstacle. Writing from the Canal zone in September 1912, a journalist, Mr. J. F. Fraser, says: "Before the Americans came the Isthmus was one of earth's pestiferous spots: swampy, miasmatic, mosquitoes carrying yellow fever and malaria. Colon was the white man's grave. Panama reeked with uncleanness and disease. The interlying

jungle country bred continuous sickness. The Isthmus is not yet a health resort. But in the immediate Canal regions it is no longer a country dangerous to health. The Americans have laid by the heels the mosquitoes which carried the disease. All likely breeding grounds or swamps are saturated with kerosene. You go for miles and the air stinks with the black slimy stuff. Nearly every ditch is smeared with it. Where pools accumulate in the vicinity of the workings, niggers with copper cans on their backs saunter about and spray freely."

The tse-tse flies of the African continent are also disease bearers. They carry about the minute, fish-like Protozoans known as trypanosomes. One of these parasites exists in the blood of large wild animals, such as buffaloes and antelopes, which are unharmed by its presence. They are known as "reservoir hosts." Presumably their races have become immune through long continued inoculation. But when this particular trypanosome is introduced by the fly (*Glossina morsitans*) into the blood of domestic cattle, horses and dogs, it gives rise to the fatal, wasting disease called "nagana." Another trypanosome causes sleeping sickness, from which 200,000 natives died in Uganda in a recent period of five years. This is known to be carried by a distinct tse-tse fly (*G. palpalis*), possibly by other species. It is now certain that the trypanosome retains its activity for many weeks after being sucked up by the fly, and it seems probably that the parasite undergoes changes and multiplication in the insect's body. This is known to happen in the case of another kind of trypanosome, a parasite of rats, which is carried by the rat-flea and the rat-louse. It is also thought that the sleeping sickness parasite, like that which causes nagana, may exist in the blood of other vertebrates besides man: the crocodile, among other animals, has

been suggested as a possible "reservoir host." All these and many other points connected with the life-histories of trypanosomes and tse-tse flies are being investigated. These studies are not merely of scientific and human interest, but of vast commercial importance in connection with the development of tropical Africa.

The plague bacillus, which afflicts rats and certain other mammals, is transported by fleas, especially the particular kind of rat-flea known as *Lœmopsylla cheopis*, to man; while numerous other insects (not to mention the spider-like ticks and mites) are either known or believed to be disseminators of disease. Indeed, all blood-sucking Arthropods may justly be dreaded as possible go-betweens, liable to convey infection from one animal to another. Moreover, certain insects carry about the microbes of disease in a purely accidental or mechanical manner. For instance, the common house-fly (*Musca domestica*) breeds in stable manure and refuse of various kinds. It also feeds largely upon filth; and its feet and proboscis become covered with microbes of all descriptions. This may be demonstrated by allowing a fly to walk over a specially prepared and sterilised plate of gelatine such as is used in laboratories for the experimental cultivation of bacteria and moulds. In twenty-four hours every footstep of the insect on the gelatine is marked by a large and varied crop of microbes. In like manner the excreta of the fly may be shown to contain infective agents. Thus, when a fly crawls over our food, or falls into a vessel of milk, these substances are inevitably contaminated; and it is known that flies which have access to the necessary infective material carry about with them the microbes of such diseases as infantile diarrhœa and typhoid fever.

In view of their manifold delinquencies insects are

often regarded as an unmitigated nuisance. But many species confer incalculable benefits upon mankind. From the standpoint of the agriculturist they are indispensable as agents in the cross-pollination of flowers. Many years ago Darwin conducted experiments which proved that the red and white clovers are self-sterile, and that insects—chiefly bees of different kinds—are responsible for all the seeds which these plants produce. Insects are no less important in orchards and gardens, for without their timely assistance our fruit trees would yield little or nothing. One observation recorded by a well-known fruit-grower (Mr. R. Brown, of Somersham, Hunts) may be quoted. "In 1907" (he writes), "when we had a very cold spring and bees could work only at brief intervals and at short distances from home, there was an abundance of fruit in three orchards close to my apiary of fifty stocks. . . . with the exception of these three orchards in the immediate vicinity of the apiary, there was scarcely any fruit in all this district."

The usefulness of predaceous and parasitic insects in checking the increase of plant-feeding pests has been emphasized more than once in the preceding pages. One more instance may be cited. In 1880, by an unlucky accident, a species of scale insect (*Icerya purchasi*) was introduced from Australia into California, where it attacked the orange and lemon trees, and spread rapidly all over the State. So terrible were its ravages that in a single year the orange crop was reduced from 8000 to 600 car loads. All attempts to stamp out the pest proved unsuccessful, and the situation became so critical that the orange-growing industry seemed doomed. In these circumstances the United States Department of Agriculture despatched an expert, Mr. A. Koebele, to Australia, where a brilliant red ladybird (*Vedalia cardinalis*) was found prey-

ing upon the scale insect. It was, in fact, the chief "natural enemy" of the pest. Large numbers of the ladybirds, skilfully packed, were sent across the ocean and liberated in the Californian orchards. The experiment was completely successful. The ladybirds settled down in their new home, checked the devastating increase of the scale, and have held the pest in subjection ever since. Small wonder that an extensive system of breeding, fostering, and distributing beneficial insects has since been adopted in the United States!

But there are some parasites and insects of prey which are harmful to the interests of mankind because they attack species that are useful. If, for example, a little Chalcid wasp lays its eggs in the aphid-feeding grub of a hover-fly, it does the gardener a bad turn. Likewise, when the parasite of a destructive pest becomes the victim of a secondary parasite (a not infrequent occurrence) the pest—not the husbandman—reaps advantage. But this phenomenon of hyperparasitism, as it is called, does not end here; for some secondary parasites are attacked by tertiary parasites, and there is some reason for thinking that even quaternary parasitism exists among insects. These extraordinary complications may be illustrated by a case which has been investigated by Dr. Howard. The caterpillars of a moth (*Hemerocampa leucostigma*), allied to our common "vapourer," defoliate shade trees in the north-eastern United States. These caterpillars are parasitised by an ichneumon (*Pimpla inquisitor*); but from cocoons spun by the full-fed ichneumon grubs a little Chalcid wasp (*Dibrachys boucheanus*) sometimes emerges—showing that the rightful inmate has been done to death by a parasite of the second order. The larva of a second Chalcid (*Asecodes albitarsis*) is known to feed within the pupa of the first—being, in fact, a parasite of the third

order; while it is believed that the *Dibrachys* itself may sometimes occupy the third place, in which case the *Asecodes* might become a parasite four times removed from the original host. In all cases of this kind the odd numbers are beneficial from the economic standpoint, the even numbers being injurious; but it is clear that the relationship of one insect to another may be extremely intricate, calling for much careful study before it can be rightly interpreted.

Proof is not wanting that the growth of noxious weeds may be checked by insects, while we have already seen that many of these creatures play an important part as scavengers in the economy of nature. A few kinds of insects are directly serviceable to mankind. Certain species constitute an important food item among savage and semi-civilised races. Thus, locusts are eaten in great quantities in Africa, termites in Africa and Australia, while a species of water-bug and its eggs are highly relished by the natives of Mexico. Many other kinds of insects are eaten, but they are for the most part regarded as luxuries rather than as staple articles of diet. Several species of soft-skinned beetles, whose blood contains large quantities of cantharidine, are used in allopathic medicine—the European blister beetle (*Lytta vesicatoria*), often called the "Spanish Fly," being the most important. The pharmacopœia of the homeopaths includes a number of insects (*e.g.* the hive-bee, the common cockroach, and the seven-spot ladybird), all of which, so the writer is assured by an expert, have proved useful in alleviating certain of the ills to which flesh is heir. The chief commercial products of insects are silk, honey, and wax. Most of our silk is derived from the cocoons spun by the caterpillars ("silkworms") of *Bombyx mori*, which are extensively cultivated in Southern Europe and the

East; but the cocoons of several large Saturniid moths have also been utilised in recent years. Three centuries ago, honey was the only sweetening agent in common use. To-day, its place is taken by cane- and beet-sugars. Nevertheless, the incomparable virtues of honey are well known, and its annual consumption in all civilised countries is still very considerable. Pure beeswax is also less in demand than heretofore, chiefly because many of the uses to which it was once put are now served by wax obtained from various plants and minerals. At the present day, the largest demand is for the manufacture of candles employed in religious ceremonial. But beeswax retains its ductility and tenacity under greater ranges of temperature than any of its competitors in commerce, and thus, for certain purposes, it remains indispensable.

Strangely enough, the family of the scale insects (*Coccidæ*), which includes very many devastating pests, also comprises a number of species which secrete substances valuable to mankind. The "manna," endowed by the wandering Israelites with a miraculous origin, was almost certainly a kind of honey-dew produced by *Gossyparia mannifera*, a coccid found on tamarisks in the Mediterranean region. The substance is still used as food by the Arabs, who call it "man." The white wax of China is secreted by *Ericerus pe-la*—a scale insect found upon the Chinese ash tree. It was formerly greatly prized, but is now falling into disuse owing to the introduction of kerosene. In India, a similar wax is secreted by a scale insect known as *Ceroplastes ceriferus*, while the wax produced by several other species of this genus has been utilised by mankind. The Mexican coccid *Llaveia axinus* yields a fatty substance from which a peculiar acid (axinic acid) is derived. This is used as a varnish, which dries and hardens on exposure to

the air; also as an external medical application in various ailments. The curiosities known as "ground pearls" are the outer shells of coccids which belong to the genus *Margarodes.* In South Africa, and the island of St. Vincent, they are collected and strung together as necklaces and bangles which are sold to tourists.

By far the most important products of scale insects, however, are lac and cochineal. Lac is secreted in large quantities by *Carteria lacca* upon the twigs of its food plants—fig, buckthorn, and other trees. It is imported from India in its natural state, and after treatment forms the basis of varnish, French polish and many other important materials. The bodies of the female lac insects also yield the crimson pigment known as "lake"; but the chief dye-producing coccid is *Coccus cacti,* the cochineal insect. A native of Mexico, it was long ago carried by man to the Eastern Hemisphere, and became thoroughly acclimatised in the Canary Islands. Cochineal, which in its crude form consists of the dried female coccids, has been largely displaced in commerce by aniline dyes; but it is still employed almost exclusively for colouring sweetmeats and confectionary, and in pharmacy. Other species of scale insects yield a crimson dye, and some of these have been known to man from the earliest times.

We see, therefore, that mankind is affected by the activities of insects in a great variety of ways. We can point decisively to many foes and many friends, but there are myriads of insects whose status remains obscure. Whether their influence is baneful or beneficial remains to be discovered. Thus, while the study of insects is interesting for its own sake, its chief justification consists in its bearing upon human affairs. This book may be fittingly concluded by an extract from the writings of Dr. S. A. Forbes. "The life-histories of insects lie at

the foundation of the whole subject of economic entomology; and constitute, in fact, the principal part of the science; for until these are clearly and completely made out for any given injurious species, we cannot possibly tell when, where, or how to strike it at its weakest point. But besides this, we must also know the conditions favourable and unfavourable to it; the enemies which prey upon it, whether bird or insect or plant parasite; the diseases to which it is subject, and the effects of the various changes of weather and season. We should make, in fact, a thorough study of it in relation to the whole system of things by which it is affected. Without this we shall often be exposed to needless alarm and expense, perhaps, in fighting by artificial remedies, an insect already in process of rapid extinction by natural causes; perhaps giving up in despair just at the time when the natural checks upon its career are about to lend their powerful aid to its suppression. We may even, for lack of this knowledge, destroy our best friends under the supposition that they are the authors of the mischief which they are really exerting themselves to prevent."

INDEX

Y

Printed by BALLANTYNE, HANSON & Co.
Edinburgh & London
4/13 2